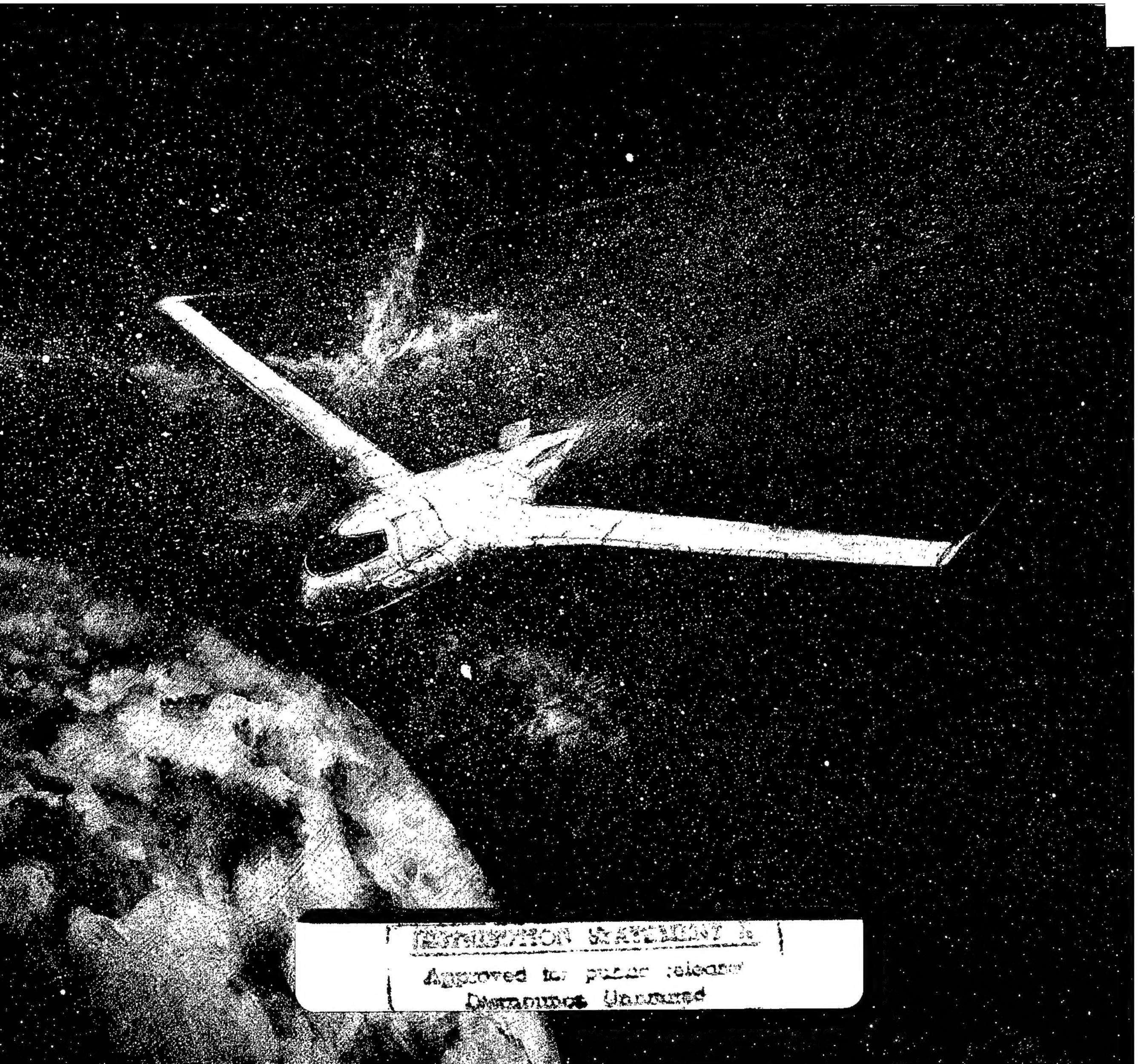

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NEW WORLD VISTAS
AIR AND SPACE POWER FOR THE 21ST CENTURY

SUMMARY VOLUME

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NEW WORLD VISTAS
AIR AND SPACE POWER FOR THE 21ST CENTURY

SUMMARY VOLUME

This report is a forecast of a potential future for the Air Force. This forecast does not necessarily imply future officially sanctioned programs, planning or policy.

Foreword

In the fiftieth year of the Air Force Scientific Advisory Board, both the Air Force and the Nation are at the brink of a new era. Our Cold War adversary no longer exists, and we now face threats which are not precisely defined. The situation is further complicated by changing alliances as much as by the absence of well known adversaries. Armed conflict around the world shows us that the world is still a hostile place, but responses which may have been appropriate during the Cold War are no longer appropriate. There appears, however, to be even more widespread pressure for the United States to remain a stabilizing force throughout the globe. Our military forces are involved in dangerous humanitarian and peacekeeping operations at an increasing rate, and anti-terrorist operations can be expected to increase as well. Although participation in these operations may require military action, we are expected to respond effectively with minimum injury and loss of life on both sides. Further, the domain of conflict is moving from earth into space and even into cyberspace. The balance of influence in the information domain has shifted from defense organizations to commercial organizations, and a similar shift will occur in space during the next decade. The crucial importance of detailed and timely knowledge and rapid communications to the successful pursuit of our new missions will demand creative use of commercial systems and technologies. This will produce an intimate intertwining of commercial and military applications to an extent not yet encountered. The intertwining will blur the distinction between threat and asset, offense and defense, and, even, friend and foe. Our future enemies, whoever they may be, will obtain knowledge and weapons better than those we have at present by making rather small investments. New sensor fusion and distributed processing capabilities will make operational distinctions such as onboard and offboard or space and ground obsolete. The rapid operational tempo enabled by complete and current knowledge, the operational demands generated by new missions, and the geographical constraints produced by a decreasing number of worldwide bases will require weapon system performance beyond that of existing systems. New technologies will permit improvement of existing systems, but new systems and new concepts will be needed to cope with the world of the 21st century.

There are strong analogies and contrasts between the world situation today and that at the time of the first Scientific Advisory Board study, *Toward New Horizons*, fifty years ago. We had won a devastating world war in 1945. In 1995, we have won the Cold War -- a war less bloody, but one which always had the possibility of destroying most of civilization. In both cases, we eliminated the threat from a powerful enemy, but then and now we have understood that preparedness and technological superiority are the keys to national security. After 1945, the United States moved to establish bases and influence abroad, but in 1995 we are reducing our physical presence abroad while we attempt to maintain a moral presence. It was clear in 1945 that the technology gains of the first half of the twentieth century should be consolidated to create a superior, technology- and capability-based Air Force which could respond to threats not yet imagined. The world which emerged from the destruction of World War II could not have been predicted in 1945, but the emphasis on technology and capability rather than on assumptions about future geopolitical scenarios served us well as we entered the Cold War. In the intervening 50 years, we have treated increasingly specific problems related to the Soviet threat. Now, that threat has disappeared. It is appropriate to return to the idea that development of broad superior capabilities through application of new technology will maintain the United States Air Force as the most powerful and effective aerospace force in the world and will enable the Air Force to

discharge its responsibilities as an equal partner with the other Services in the defense of the Nation.

These considerations and the broad applications of new, largely commercial, technologies which are now, or soon to be, possible have led us to present the conclusions of the participants of *New World Vistas* as an integrated, capability-based, report. Realization of these capabilities will permit future members of the Air Force of all ranks to know, to plan, to act, and to evaluate in the detail appropriate to their responsibilities. One should not doubt that the 21st century Air Force which will be enabled and, indeed, demanded by its new capabilities and responsibilities will hardly be similar to the Air Force of today. The changes will be as profound as those experienced by the Army in moving from horse to tank or by the Navy in converting from sail to steam.

The Board wishes to thank the numerous Air Force people and organizations for their tremendous help in the preparation on *New World Vistas*. Special recognition goes to the United States Air Force Academy and the Air University for their assistance and counsel.

Finally, we have endeavored to define the capabilities which will result from emerging technologies during the next three decades, and we have attempted to point the way toward achieving those capabilities as the Air Force enters the Information Age. We hope that our work will succeed in helping to prepare the Air Force for the approaching revolution in the use of military power.

Dr. Gene H. McCall
Chair, USAF Scientific Advisory Board
Study Director, *New World Vistas*

John A. Corder
Major General, USAF (Ret)
Deputy Study Director

15 December 1995

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Chapter I

Technologies for Arming the Air Force of the 21st Century

1.0 Introduction

New World Vistas is a study about the Air Force. It is about technology. It is about ideas. Most of all it is about the defense of the United States. The Secretary of the Air Force, Dr. Sheila E. Widnall, and the Chief of Staff, General Ronald R. Fogleman, directed the Air Force Scientific Advisory Board to identify those technologies that will guarantee the air and space superiority of the United States in the 21st century.[1] We have taken the charge as an obligation to find and to create new ideas. We believe those ideas will make the Air Force of the future effective, affordable, and capable in seamless joint and multinational operations in which it achieves its purpose "to fight and to win the Nation's wars."[2]

New World Vistas is documented in detail in over 2000 pages of monographs collected in 15 volumes. The study participants are listed, and abstracts of their work are contained in Appendix B. There are many good ideas and careful descriptions of them in the 15 volumes. In addition, there is a Classified Volume[3] and a volume of important ancillary information obtained during the conduct of the study. And finally, this Summary Volume distills the major ideas from the monographs and integrates them into concepts that will produce a discontinuous or quantum enhancement of the effectiveness of the Air Force. We attempt in this volume to provide compelling reasons for pursuing these ideas, and we establish a path that stretches from today into the future. The definition of the path includes suggestions for significant incorporation of commercial technologies and practices into Air Force operations, and it includes suggestions for both change and reinforcement of the ways that the Air Force pursues science and technology goals. Our suggestions are based on the principles embodied in the concept of Global Reach-Global Power, which directs the Air Force to be capable of projecting power and influence worldwide.

We understand the uncertainties that accompany any attempt to predict the future. We may generate ideas that will be notable as humorous objects for future generations rather than notable as accurate visions of the future. We can only base our suggestions on our experience and on our estimates of the needs of the future. Most predictions become increasingly inaccurate with time after a decade or so has passed. Experience has shown, however, that carefully considered predictions are useful in defining new areas of endeavor that lead to new discoveries even if the discoveries are not those predicted. Thus, armed with caveats, confidence, and, perhaps, a small amount of vision we plunge into the task of defining technologies that will arm the Air Force of the 21st century.

We assert that the emphasis of Air Force technology must change. The Cold War presented a single adversary who had well known tactics, systems, and capabilities. Cold War military technology responded to the threat by developing weapon systems designed to respond to particular scenarios. In the process of development, we produced generic capabilities, but they mainly derived from the process of responding to the Soviet threat. System cost was always an important parameter, but it was never the predominant consideration.

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1. Memorandum to Dr. McCall from General Fogleman, CSAF and Dr. Widnall, SecAF - Appendix A.
2. General Ronald R. Fogleman, Address to Air Force 2025, Maxwell AFB, AL, 6 September 1995.
3. Classified Volume - on file in SAB office

Now, however, no well defined enemy exists. There are scenarios that suffice for some planning purposes, but they are of questionable reality. Rather than responding to a few particular scenarios, military technology now must respond to diverse situations. Cost has become a major factor in the development of all systems. We must also recognize that commercial technologies, which are developing at a rapid pace, have significant military applications. The Air Force must take advantage of new commercial technologies and must counter their use in adversary systems. It is essential that future systems be based on capabilities and cost, perhaps on an equal footing, rather than on solutions to specific problems.

There are two subjects about which the report is silent. The first is National Missile Defense. We do not believe the topic to be unimportant, and it will be apparent that several of the technologies we discuss are applicable. We found, however, that National Missile Defense is embroiled in politics too complex to permit detailed concept definitions to be of use at present. The second subject omitted is Nuclear Weapon Technology. That subject, too, is important, but nuclear weapon technologies are developed outside the Air Force, and the nuclear forces are, at present, prohibited from pursuing new ideas of design or delivery. We do, however, address problems associated with defense against weapons of mass destruction.

Chapter II will address the capabilities which are enabled by the new technologies. We will emphasize the interaction of technologies and capabilities, and we will show how new information sciences connect and enhance capabilities. Next, we will delineate the technologies. A striking feature of the list of technologies is that it is short. From a short list of new technologies and their supporting technologies the Air Force will derive amazingly superior capabilities. Chapter III will suggest what the Air Force should do, what they should stop doing, how to pay for it and how to make it happen. Chapter IV will conclude with organizational considerations and recommendations.

2.0 Fundamental Considerations

We have attempted to define capabilities and technologies that transcend particular missions and apply to all scenarios. We have not divided our recommendations into neat, well-defined categories. We tried, but we found that the power of the technologies and concepts that we recommend is that each cuts across several fundamental capabilities. The Attack Panel Volume presents a detailed method for inverting the matrix and discussing capabilities in terms of tasks to be performed.[4] We believe that the applications will be readily apparent when explained in detail. For example, knowledge and control of information is necessary for all missions, whether in peace or war, logistics or combat. All missions depend on communications and reconnaissance and, therefore, increasingly on space assets. As space assets become increasingly important, space control becomes a necessary part of all missions. Throughout the Force, the necessity of accurate, absolute positioning and timing is apparent. The most efficient way to supply this service is through space assets such as an enhanced, countermeasure-immune Global Positioning System (GPS). A technological thread which runs through many future applications is materials development. Strong, lightweight materials and structures will enable many capabilities in space, aircraft, and weapons.[5]

4. Attack Volume
5. Materials Volume

We know that reduced cycle time is a true force multiplier. It is characteristic of reduced cycle time that all components of the Force must operate at a higher tempo. If an airlifter is late with supplies, an attack mission will be delayed, and the choreography of an entire operation can be disrupted. The sensor systems that enable precision delivery of munitions can also be used in aircraft self protection. Technologies and functions will influence all capabilities. The Force will become so tightly integrated in function, and will be so tightly coupled to allies and the other services that boundaries between capabilities will become blurred if they exist at all.

For the purposes of *New World Vistas*, we have assumed that:

- The Air Force will have to fight at large distances from the United States. Some operations may be staged directly from the Continental United States (CONUS). Operations may persist for weeks or months, and they must be executed day and night in all weather.
- The site of the next conflict is unknown. The Air Force must be prepared to fight or to conduct mobility or special operations anywhere in the world on short notice.
- Weapons must be highly accurate, must minimize collateral damage, must minimize delivery and acquisition costs, and must enhance, and be enhanced by, aircraft capabilities.
- Platforms that deliver weapons must be lethal and survivable. They must establish air superiority in areas that are heavily populated with surface to air missiles (SAM's), and they must carry the attack to all enemy targets, fixed and mobile.
- Adversaries may be organized national forces or terrorist groups.
- Targets may be fixed or mobile and may be well concealed. Target classes will span the range from personnel to armored vehicles and protected command centers and information systems. Operational geography will range from classical battlefields to cities and jungles.
- Adversary capabilities will steadily improve and will be difficult to anticipate. For example, the Air Force must be prepared to defend against improved SAM's, low observable aircraft, cruise missiles, directed energy weapons, and information attack.
- The Air Force must detect and destroy chemical, biological, and nuclear weapons and their production facilities.
- There will be peacetime missions in areas of local conflict. Aircraft must be protected against SAM's and ground fire by means other than offensive attack.
- Increasing the pace of operations increases the effectiveness of all operations.
- Cost will be equal in importance to capability.
- The number of people in the Air Force will decrease. Individual performance must be optimized.

2.1 Increased Tempo

All missions establish a cycle of knowing, planning, acting, and assessing. The cycle repeats, and if we are to minimize losses and maximize effect the cycle must repeat as rapidly as possible.

Increased tempo of operations makes the Force appear larger.[6] If an attacker can strike an enemy twice in the time necessary for the defender to respond once, the attacking force appears to the defender to be twice as large as it actually is. Given fixed funding to improve capability, though, one can ask whether it is more effective to spend the allocation on improving the performance of existing weapons or to spend it on increasing delivery, or sortie rate. Improvements in performance are produced by improved accuracy of weapons, for example. The two categories are not completely independent, of course. An accuracy improvement in weapons can reduce the number of sorties required per target. Thus, more targets can be struck in a given time, and the force appears to be larger. A simple mathematical theory to analyze the situation described was devised by F. W. Lanchester,[7] a British aeronautical scientist, in 1907. Although modern warfare is more complex than envisioned by Lanchester, his theory has survived remarkably well, and we use it here to motivate the reader to accept our concentration on increasing

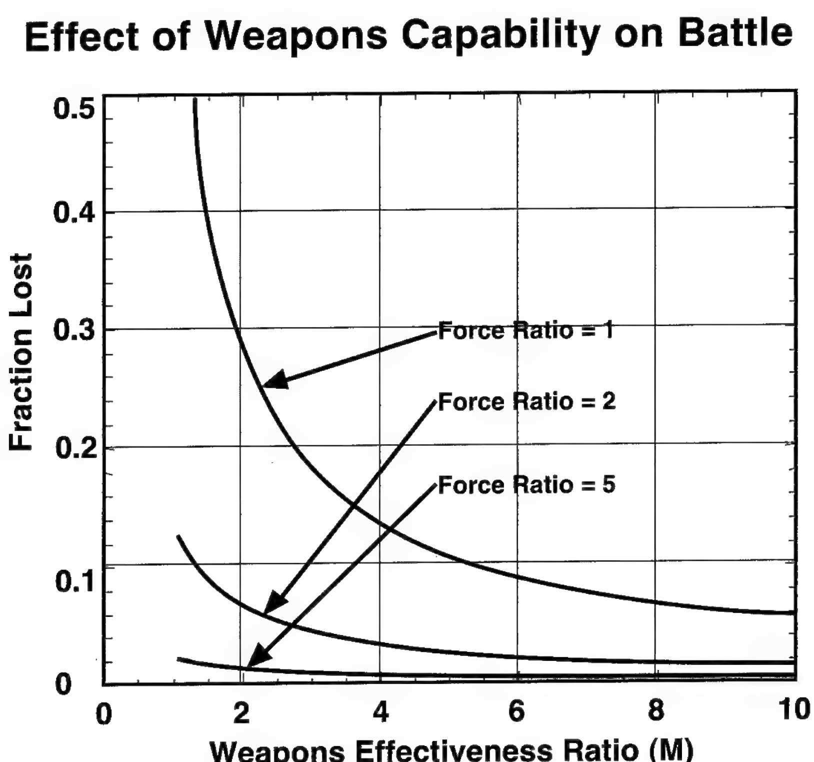


Figure I-1(a)

6. Attack Volume
7. James R. Newman, *The World of Mathematics*, Simon and Schuster, New York, 1956, vol. 4, pp 2136-2157

the tempo of operations. We refer the reader to the reference for a complete description of the Lanchester theory, but we display the results of the theory in figures I-1(a) and I-1(b). Figure I-1(a) shows the fraction of an attacking force lost as a function of weapon effectiveness, M. One can think of effectiveness as accuracy, for example, figure I-1(b) shows the fraction of an attacking force lost as a function of the ratio of the size of the forces. For the purposes of this discussion it will suffice to observe that increasing the force size reduces losses faster than does increasing weapon effectiveness. Because of budget limitations, it is unlikely that we can justify large increases in numbers of aircraft, weapons, or people. Therefore, we will concentrate on technologies which increase the apparent force size through increased tempo of operations.

Effect of Apparent Force Size on Battle

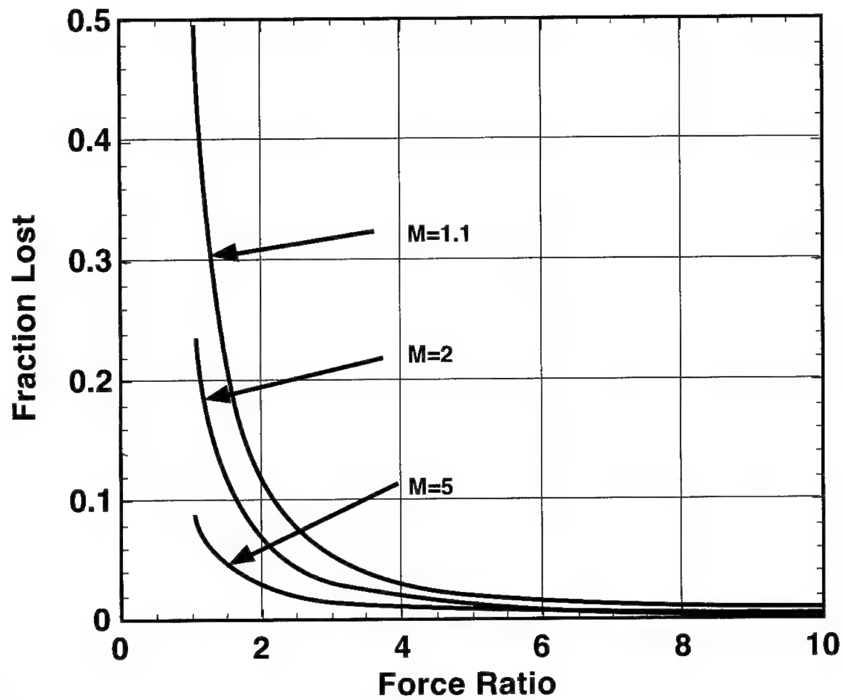


Figure I-1(b)

It is certain that most of the weapon systems that will exist in a decade exist now. The F-22 will be the only new aircraft available in a decade. An aircraft based on the Joint Advanced Strike Technologies (JAST) may appear a decade after that to replace the F-16. By the time that the F-22 and JAST appear, new technologies will be available to enhance their performance, but both aircraft are being designed using extant technologies. Thus, in addition to long range projections, we propose technologies and concepts to enhance the current force during the next ten years. These ideas will also lead to better capabilities for the F-22 and JAST. The technologies that will enhance the early 21st century Force are related to improved weapons, improved

communications, and improved generation and exploitation of information. Improvement in the reliability of components such as avionics will be necessary to reduce logistics costs and to maintain extended high tempo operations.

The aircraft now planned for the 21st century, such as the F-22, are superior to existing aircraft in the United States and abroad. They will not, however, produce a discontinuous change[8] in the nature of aerospace warfare. Discontinuous change can occur in several ways. It usually occurs as a result of the introduction of new weapons that rapidly transcend the capabilities of older weapons. Firearms were a discontinuous change over weapons propelled by humans. The machine gun and the tank made the horse obsolete. The airplane destroyed the idea that distance provides protection. To a lesser extent new delivery systems or new tactics can produce a discontinuous change in warfare. The precision guided munition and the stealth aircraft are examples of delivery systems. For certain targets, the precision guided munition increased the destructive power of munitions by as much as a factor of 1000, and the stealthy aircraft reduced the effective range of surface-to-air missiles by a substantial amount. The introduction of naval tactics by Rodney at the Battle of Saints in 1780 and the introduction of the concept we now call reduced cycle time by Nelson at the Battle of Trafalgar in 1805 are examples of the force of a new philosophy of warfare.

3.0 The Future Force

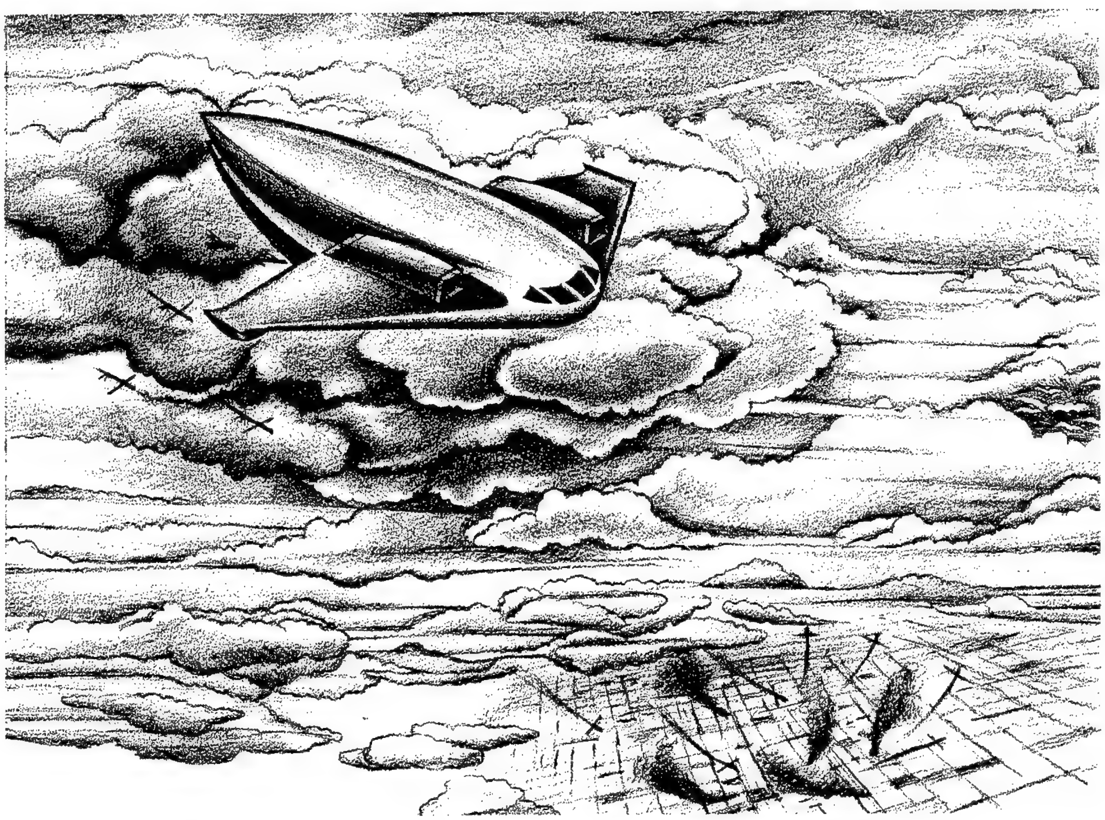
What then are the discontinuous changes of the future, and how are they enabled by technology? Both concepts and technologies are described in detail in subsequent volumes. In this volume we delineate the major features. We will set the stage for the discussions that follow by describing the Air Force that will be built from the concepts and technologies proposed.

There will be a mix of inhabited and uninhabited aircraft. We use the term "uninhabited" rather than "unpiloted" or "unmanned" to distinguish the aircraft enabled by the new technologies from those now in operation or planned. The "unmanned" aircraft of the present have particular advantages such as cost or endurance, but they are either cruise missiles or reconnaissance vehicles. The "uninhabited" combat aircraft (UCAV) are new, high performance aircraft that are more effective for particular missions than are their inhabited counterparts. The UCAV is enabled by information technologies, but it enables the use of aircraft and weapon technologies that cannot be used in an aircraft that contains a human. There will be missions during the next three decades that will benefit from having a human present, but for many missions the uninhabited aircraft will provide capabilities far superior to those of its inhabited cousins. For example, shape and function will not be constrained by a cockpit, a human body, or an ejection seat. We believe that the design freedom generated will allow a reduction in radar cross section by at least 12 dB in the frequency bands currently addressed, compared to existing aircraft. A 12 dB reduction in aircraft cross section will reduce the effective range of enemy radar by a factor of two and area coverage by a factor of four. At this point we reach the limit of passive radar cross section reduction, and active methods must be developed. Also, reduction of infrared emissions is an important area where substantial improvements can be made. Other advantages

8. We will use the terms "discontinuous change" and "revolutionary" interchangeably

of the UCAV will be described later. There is the possibility of extending UCAV performance into the hypersonic range to enable strikes from the CONUS on high value targets in minutes.

Large and small aircraft will project weapons. At present we think of large aircraft as bombers, tankers, surveillance aircraft, or air launched cruise missile (ALCM) launch platforms. In the future large aircraft will be the first to carry directed energy weapons, and their entry into combat as formidable tactical weapons will cause a discontinuous change in aerospace warfare. Eventually, after establishing their value aboard aircraft, directed energy weapons will move into space. Small UCAVs can be carried aboard and launched from large aircraft to provide intercontinental standoff capability.



Attack by Low Observable UCAVs Deployed by Airlifter

Explosive weapons will be substantially more accurate than those of today, and explosive effectiveness per unit mass will be higher by at least a factor of ten than those of today. As a result, a sortie of the future can be ten times more effective than one of today. Weapon types will range from inexpensive enhanced accuracy weapons without sensors to GPS directed weapons

with better than one foot accuracy to microsensor directed microexplosive systems that kill moving targets with grams of explosive.

We must extend airlift capabilities. The current generation of military airlifters and commercial transport aircraft will be useful for the next three decades, but replicating these aircraft with evolutionary upgrades will not provide the necessary capabilities. Even the addition of the Civil Reserve Air Fleet (CRAF) cannot provide enough airlift capacity for the future, and while commercial airlifters will form an important component of the future airlift fleet, their capabilities are limited, and they cannot be exchanged one for one with military airlifters. The future airlifter should be large (10^6 pounds gross takeoff weight), efficient (1.3-1.5 times current aircraft), and long range (12,000 nm). It should have point-of-use delivery capability through precision airdrop as a routine delivery process. Full airdrop capability will reduce theater infrastructure requirements for both the Air Force and the Army at forward locations. Rapid tempo of operations will require rapid resupply. As we take advantage of the operational possibilities enabled by technology, the Air Force of the future will be limited by logistics considerations just as surely as were the forces of Hannibal and Napoleon. We must pay close attention.

The future force will become efficient and effective through the use of information systems to enhance US operations and to confound the enemy. The infancy of this capability is represented today in the F–22. Information and Space will become inextricably entwined. The Information/Space milieu will interact strongly with the air and ground components, and it is here that commercial technologies and systems will have the largest presence. Defense will not be a driver of important technologies in this area. Surveillance and reconnaissance will be done worldwide from commercial platforms, and international conglomerates may own some of those platforms. High resolution mapping services from space will be purchased. Worldwide weather monitoring will be possible, although current systems are not capable of adequate precision. Precise timing and positioning services will be provided by a new ultra precise, jam resistant Global Positioning System (GPS). Communication of information and instructions throughout the Force will be instantaneous over fiber and satellite networks. Computers and displays will be common, commercial units. Even avionics processors and data busses will be purchased off the shelf. As we improve the capabilities of information equipment, we should remember that the human is an integral part of the system. We must improve the capabilities of the human-machine interface as we improve the machine.

There is an area where development of defense information systems may diverge from development of commercial systems. Those are *systems used in Information Warfare (IW).* The use of "information munitions" in offensive operations will become an essential component of warfare. The use of "information munitions" will, however, make unusual demands on software and equipment. At present, it appears as though Information Warfare is more of a "bag of tricks" than a system of warfare. As the technologies are better defined, this will change. We must constantly make IW more robust and more effective. Information Warfare has three components. One is the method, or core, of IW which uses computers and software to deceive and destroy enemy information systems. The second component is deployment. Deployment may be as simple as connecting to the Internet, or it may require special communication systems, high power microwave systems, special forces action, or surreptitious individual action. The final component is Defense. Defensive IW will be pursued by the commercial community because of the obvious effects that malicious mischief can have on commerce. The military

problem is, however, likely to be different enough that some effort will be required. The commercial solutions should be monitored closely. It is the union of method, deployment, and defense which creates the Information Munition. These components must not become separated if maximum effectiveness is to be achieved.

Space and space systems will become synonymous with effective operations. In addition to government investment in military systems, US companies will have large investments in space and information systems. The protection of our assets and the denial of capabilities to an enemy will be essential. The future Force will, eventually, contain space, ground, and airborne weapons that can project photon energy, kinetic energy, and information against space and ground assets. Many space and information weapons will destroy. Others will confuse the enemy and weave the "bodyguard of lies"[9] that will protect our forces.[10]

Sensors and information sources will be widely distributed. Sensors onboard fighter aircraft will continue to be important, but they will form a progressively smaller part of the total information source for combat operations. Fighter-mounted sensors, too, will supply information to companion craft as often as they provide information to their bearer. There will be sensors functioning cooperatively aboard small, distributed satellite constellations, sensors aboard uninhabited reconnaissance aerial vehicles (URAVs), sensors aboard weapons, and sensors on the ground delivered by URAVs. We often speak glibly about enhancing capability through information, but we as often forget that information originates as data from active and passive sensors.[11] The power of the new information systems will lie in their ability to correlate data automatically and rapidly from many sources to form a complete picture of the operational area, whether it be a battlefield or the site of a mobility operation. In particular, the accuracy of a single sensor and processor in identifying targets or threats is severely limited. Detection and identification probabilities increase rapidly with sensor diversity and the false alarm probability and error rates decrease correspondingly.

Affordability restrictions demand caution at this point. For the technologist, the intellectual lure of ultra precise sensors and control systems aboard munitions flying at hypersonic speeds is seductive. But, sensors and control systems constitute a large fraction of the cost of a munition, and we see no substantial change to this situation in the future. We properly laud the improvement in capability generated by precision guided weapons. We sometimes forget, however, that Precision Guided Munitions (PGMs) do not always produce an increased operational advantage proportional to their increased cost. This situation can change as a result of reduced sensor costs in the future or as the result of reduced performance requirements. It will always be cheaper to carry reusable precision sensors aboard a reusable delivery platform and either to eliminate guidance and control on board the munitions entirely or to use rather inaccurate onboard systems. The trade between munition precision and platform precision will, of course, depend on the survivability of the platform at appropriate release distances and the dependence of cost on munition accuracy. It may be possible to reduce the cost of precision delivery by building reusable, close approach delivery platforms that have precision positioning and

9. Winston Churchill, said to Josef Stalin; Teheran; November, 1943
10. General Ronald R. Fogleman, Speech to NDU/NSIA Global Information Explosion Conference, National Defense University, 16 May 1995
11. Sensors Volume

sensing systems, reproducible weapon release, and wind measuring equipment onboard. Munitions can be built with low drag coefficients. Significant cost reduction will result from the reuse of sensors and processors. The munition can either have no guidance or can have simple inertial or GPS guidance and low precision controls. This option favors the low observable UCAV for attack of mobile and protected targets.

Finally, the loop must be closed. The operational components of the Air Force must plan together, function together, command and be commanded, exchange information, and assess results collegially with each other, other services, and allies. Planning and directing must be done in parallel rather than in series to sustain high rate operations. Plans must be analyzed continuously at all levels by simulation. We refer to the construct that makes this possible as a complete "internetting of nodes" and as a seamless "operation across networks."[12] A node can be an airplane, a general, an Army private, a tank, or a UCAV. A collaborating network may be operated by the US Army or by an allied command. Internetting provides for the nearly direct connection of one of the nodes to any other node. Communication channel, processor, and terminal considerations determine the fundamental physical limitations, but with the exception of radio frequency (RF) channels, these limitations are vanishing as practical limitations to the internetting process. Even RF data channel capacities are increasing as the result of new compression algorithms and error correction schemes. Major difficulties remain, however, in establishing priorities for information transfer and in maintaining adequate security. Capture of nodes must not compromise system integrity. Elimination of these difficulties will be neither easy nor inexpensive. *We must solve the important security problems before the full impact of information sciences can be realized.*

This low resolution snapshot of the Force was intended to give the reader an idea of the extensive enhancement and integration of capabilities that will be possible in future decades. We hope that the applications of the new technologies are so profound that they are obvious and compelling, and we hope that they stimulate the reader to create personally pleasing combinations of capabilities. For example, improved stealth provides higher effectiveness against both aircraft and SAMs in establishing air superiority. Improved aircraft performance, say through UCAVs will increase survivability in high threat areas. Together, stealth and performance will reduce the reliance on electronic countermeasures with an accompanying reduction in cost and system volatility, and when directed by offboard information and passive sensors, they have the surprise value of a silent force. Large airlifters with point of use delivery capability can provide the military equivalent of "just in time" supply from CONUS, if necessary, with cost reductions and efficiency increases that are as large as those realized by commercial industries. Accompanied by airlifters carrying UCAVs and directed energy weapons for self defense, the airlifter fleet will become a survivable offensive weapon system in high threat areas. Distributed space systems can revisit areas of interest at rates not now possible. Distributed space sensors can operate cooperatively with staring sensors aboard Uninhabited Reconnaissance Air Vehicles (URAVs), which continuously monitor important targets, to optimize the collection and use of intelligence information.

A word about the application of commercial technologies is appropriate. No one doubts that many commercial technologies are applicable to military problems and that their use can

12. Information Applications Volume

reduce system costs and improve utility. There are, however, obligations concomitant with their use. Commercial technologies accompany commercial practices. We must be prepared to change requirements and operating procedures to agree with commercial practice if we are to make efficient use of commercial technology. *In the fields of space, communications, and information, the time from concept to deployment must be no longer than two years. Information systems should be replaced in five years.* Many processes can be improved by an injection of commercial practice, but the price paid for the improvement will be uncertainty in ultimate performance and survivability. Replacement of damaged units will become more acceptable than hardening to reduce cost. A program development culture that generates continuous improvement from humble beginnings rather than ultimate initial performance will be demanded. The new development culture will require an operational culture that can accept less than optimum performance today in exchange for rapid improvement tomorrow. We must demand reduced cycle time in procurement just as we will demand it in execution.

In the following chapters we will provide much more detail about technologies and concepts. Ultimately, however, the Panel Volumes and the Panel Members provide the depth necessary for implementation.

4.0 Revolutionary Concepts in Context

The word "revolutionary" is in common use, and overuse, today. *New World Vistas* proposes concepts that we believe to be revolutionary. The word has been used to mean many things, and it is useful to put the term into a context within which we can discuss new technologies and their use. The word is frequently used to identify a "silver bullet" -- a single concept or device that will immediately produce the ascendancy of the user's forces over those of the user's adversaries. The world is not like that. Science, technology, and military inventions are not like that. Nearly always, it is the evolutionary follow-on of a new concept that produces a revolution in capability. For example, the nuclear weapon was the most revolutionary weapon ever invented. It not only changed the nature of warfare but also it changed the nature of all interactions among nations, and it changed the way all science was viewed by the public. The first two nuclear weapons, however useful as a demonstration of the principle, would not, had they been duplicated many times, have had that affect. It was the evolutionary development of the thermonuclear weapon from the fission weapon coupled with the evolution of the ICBM from the V-2 that produced the profound effects on society. Frequently, too, it is the association of well-known principles in an innovative way that produces the revolutionary result. The geometric arrangement of junction voltages between semiconductors in an unusual way produced a transistor. The evolutionary development of Complimentary Metal-Oxide Semiconductor (CMOS) and integrated circuits has led to the information revolution.

Thus, we can seldom expect to produce truly revolutionary effects with the first manifestation of a new technology. In recognition of this fact, demonstrations should not include all aspects of a new technology. Smaller steps should be taken to minimize the total cost and to permit more flexibility. The first attempt to apply new concepts is a necessary, but not sufficient step. In military systems, the second step in the development of a radically new concept must be determined after operational deployment. The warfighters will use the system in innovative ways not described in the manuals, and it is this experience that will define the path to revolution.

We should keep some general guidelines in mind:

- The relationship between revolutionary and evolutionary concepts is complex and complementary.
- Revolutionary ideas often point the way to later applications which are far more useful than the original idea.
- Early applications of revolutionary concepts should not be required to be complete and final weapon systems.
- Identification and development of revolutionary concepts require intuition, innovation, and acceptance of substantial risk.
- We must be prepared for a failure rate greater than 50 percent.
- Most revolutionary ideas will be opposed by a majority of decision makers.
- We must remember that science and science fiction are related only superficially.

Examples of all these points abound. We invite readers to substitute their favorites.

5.0 The Report

The Air Force must become a force that is tightly integrated within itself, with the other Services, and with allies. It is difficult to write a report on *New World Vistas* that reflects the integration and, at the same time, displays the component parts in a way that makes their development clear. We will try to expose the nature of the problems and their solutions by writing the report from two aspects. In Chapter II, we will remove technologies from their applications and describe them separately, and we will describe concepts that collect the technologies into integrated units. The reader should constantly imagine each technology and each concept feeding and deriving support from the others.

In Chapter III, we will suggest the immediate tasks that will spawn the new technologies. We will even suggest a few fields now pursued which should be abandoned, although our knowledge of Air Force Science and Technology programs is not deep enough to make the list complete. In Chapter IV, we will suggest changing some of the management concepts for the Air Force Laboratories, and we will identify some characteristics of the Scientific Advisory Board (SAB) that can be used to make it more effective. It is well known, however, that self analysis is unlikely to be accurate.

Finally, we observe that the relationship of the Air Force to technology is a living, changing one. It is the character of the relationship and the dedication of the people in the Air Force to the application of the newest principles of science and technology that has made it the envy of the world. To the extent that *New World Vistas* is a part of this process, it should stimulate discussion and analysis as much as it defines new concepts, and its proposals are debatable. If our work causes the Air Force to examine and embrace the notion of discontinuous enhancement through technology, we have succeeded. If a few of our ideas find their way into the Force of the future, our efforts will have been well repaid.

Chapter II

Capabilities and Technologies

1.0 Introduction

We define a set of capabilities which, we believe, are synonymous with an effective Air Force, and we believe that others will agree to their importance. They do not match accepted Mission Areas for two reasons. We experimented with Mission Areas at the Spring Workshop[1] of *New World Vistas*. We found that Mission Areas were closely related to existing capabilities, and we naturally began to think of new technologies as producing evolutionary enhancements to existing capabilities. Many participants thought that the categories were too narrow and restrictive. Second, when we collected the new ideas they formed categories which mapped into the Mission Areas, but the ideas each applied to several areas, and we began to generate a complex set of charts. Constructing the map is straightforward and instructive, but we leave it as an exercise for the interested reader. We decided to form a set of categories which were natural ones for the technologists and, simultaneously, meaningful for the operators. These primary capabilities, as viewed by the technologist, are entirely consistent with the capabilities of Global Reach-Global Power and the Air Force Core Capabilities. These categories form a bridge for discussion between scientist and warfighter, and we felt that to be a dominant factor in an activity such as *New World Vistas*.

We reduced the list of essential capabilities to a basic few. We intentionally made the categories broad to encourage broad thinking about important problems. The list is short and is meant to be viewed in the context of the Air Force concept of Global Reach-Global Power. The primary capabilities are:

- Global Awareness
- Dynamic Planning and Execution Control
- Global Mobility in War and Peace
- Projection of Lethal and Sublethal Power
- Space Operations
- People

One can argue that the categories mix support, or infrastructure, and operational capabilities, and that is, indeed, true. However, the 21st century will be characterized by an increasing reliance on devices which operate at the edge of technology and by an increasing worldwide infrastructure in space. Therefore, the education and training of Air Force people will enable all operational capabilities. We must remember, too, that space will contain major threats to the security of the Nation and its Forces as well as containing important operational assets. We believe that Space Operations and People deserve equal footing with the other capabilities.

Each of the capabilities expand to include many subcategories, and each depends on many technologies. In this chapter, we will describe the capabilities and relate the technologies to them. The major technologies will be listed in Chapter III. Do not expect completely logical one-to-one correlations or extremely detailed expositions in this volume. Those features are

1. *New World Vistas* Spring Workshop, Maxwell AFB, AL, 2-5 May 1995

characteristic of the Panel volumes. We will direct the reader to the appropriate volume through footnotes.

It is our intent to emphasize the close integration of the technologies and the capabilities with one other. Therefore, we will refer to some systems or technologies several times in the chapter. This is not an unintentional redundancy. It is to impress on the reader that capability is based on dependency. We can not afford -- financially or operationally -- to have all systems self contained to the extent that they are now. Offboard sensors and weapon control provide enhancement of capability far beyond their cost. Replicating information functions on all weapon platforms is not only extravagant, it is also less operationally effective than central information processing.

The list of essential capabilities reflects the effect of uniting the Air Force with technologies that will produce a discontinuous enhancement of Air Force capabilities. Those technologies are variously named "high leverage", "revolutionary", or "explosive growth" technologies. A more useful and accurate description is that certain technologies are "coming of age". Information technologies are now an essential part of all Air Force activities, and they will be even more important a decade from now. We should remember, though, that computer programming was an undergraduate course at many universities in the 1950's. The transistor, which makes it all possible, was invented in the 1948. We illustrate this concept intuitively in Figure II-1, which is a graph of a parameter, which we call "importance", that started with a value of 1 and doubled every four years. Importance could be computer speed, PGM performance, or another important measure of the value of a technology.

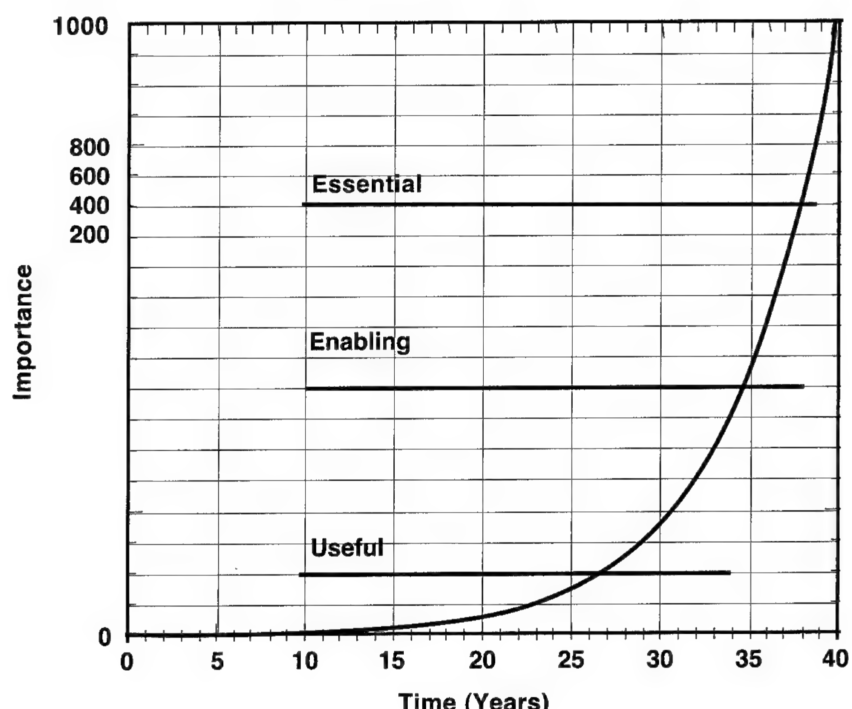


Figure II-1

If one looks back from a period when the importance has grown by a factor of 1000 from its initial value, the growth seems to be explosive for the past most recent decade, but it seems that nothing much happened for the first 20 years. In fact, the relative growth was constant. This is not a new observation, but it makes the graphical point that in *New World Vistas,* we are trying to define capabilities that make immediate and efficient use of technologies which have passed the "700" point. Next, we will show uses and effects of the technologies which have passed the "400" point. Finally, we will suggest new capabilities which will demonstrate the use of technologies at the "100" point. One could, for example, identify these states with information technologies, space technologies, and directed energy technologies, respectively.

2.0 Global Awareness

Global awareness means that the Air Force can use affordable means to derive appropriate information about one or more places of interest after a delay which is short enough to satisfy operational needs. This is the goal of the capability we call Global Awareness, but the definition is far too vague to be of practical use. We will explore the idea by describing the strengths and weaknesses of the systems which can make it possible. There is a strong commercial component here, and we will show the connection between military and commercial applications. The systems which enable Global Awareness form a truly joint capability. Although we describe Global Awareness in an air and space context, the application to sea and land should be clear.

Technology has for years made it possible to build relatively inexpensive observation platforms in space which will deliver images from optical or radar sensors at resolutions better than one meter. Images from a few systems are commercially available now, and there will soon be competition among companies to deliver the best product. The Air Force, or the Defense Mapping Agency, should purchase these products for mapping the world at a resolution of one meter. This provides Global Awareness of a sort, but the latency time for a world map is expected to be 90-180 days with local updates of, say, 100 mile square areas in 24-48 hours. A dedicated system could provide high resolution images of several small areas daily. This is an essential capability, but it is not completely adequate.

Mapping at present consists of a huge number of products both digital and analog constructed on an array of coordinate systems with varying precision and accuracy. First a common grid based on WGS-84 should be defined. It may be useful to supply maps which are expressed in unique coordinates, but the source for all these maps should be a common database. The database can be supplied by the commercial imaging system described above. It is not likely, however, that absolute accuracy will be one meter, but it is possible to devise a GPS-based method of calibrating the images. Collaboration with the commercial supplier in satellite design could make the calibration task easier. The goal of precision mapping should be to equip each aircraft and planning system with a map of the entire world to one meter accuracy. The map will require 10-20 terabytes with suitable compression. After the creation of the initial map, only updates need be supplied routinely. Onboard storage will minimize data transmission needs. Storage density will be adequate in a decade. We refer to the high resolution onboard digital map as the "onboard world."

The "onboard world" will enable the ultimate in moving map navigation and self contained, undetectable terrain avoidance. The information can be coupled with navigation aid and

airport information supplied by commercial vendors. All Air Force aircraft will have the navigation database to fly anywhere, anytime, on any route independent of external data.

2.1 Distributed Satellites

The manifestation of the concept of Global Awareness is one of distributed constellations of small satellites[2] which cooperate with airborne and ground sensors. We must divest ourselves of the mindset that spatial resolution is the only criterion for evaluating surveillance systems. There are indications that one can derive target information from spectral data coupled with low resolution position information. A system of satellites each having a spatial resolution of 10 meters and, say, 100 spectral bands in the visible and infrared could provide worldwide coverage instantly on demand. Communication limitations will restrict the number of areas which can be covered simultaneously, but even this restriction will disappear as laser cross- and downlinks become commonplace. Laser links will approach the capacity of fiber, where 40 Gb/s is becoming routine. Onboard processing and compression can increase information transfer rates. Because of higher cost and the $1/R^4$ dependence of signal on satellite altitude, Synthetic Aperture Radar (SAR) systems will be fewer than optical systems, and SAR images will have a latency time of an hour or two.[3] Active systems could also include Light Detection and Ranging (LIDAR) for chemical and biological agent detection in clear weather and for precision weather observations. These systems will provide missile warning and will enable the tracking of mobile rocket launchers and SAM systems. They can also provide weather information at a level of detail appropriate for combat and mobility operations. High resolution active and passive systems can augment the lower resolution data at revisit rates of one per day. The cooperative, distributed satellites will establish long baselines for precise location of radio frequency emitters on the surface and in space. It will be possible to locate an emitter to an accuracy that will permit the launch of a precision guided munition using GPS coordinates even if transmissions cease.

Onboard processors will make it possible to identify and track moving targets to the extent that tracking and identification can be done by infrared hyperspectral systems. Complete Airborne Warning and Control System (AWACS)-like performance will be enabled at the second stage of deployment[4] with a combined air and space based system. High resolution radar from space can be enabled by the capability to deploy large, lightweight space structures. Given power available in space, continuous operation of high resolution radar will necessitate antennas having diameters of kilometers. Development of appropriate structures and materials coupled with technologies for correcting RF wavefronts to compensate for antenna imperfections will make space based radar possible. If one requires only limited coverage, say 500 km (the limited diameter), the peak power of a space based radar system can be increased by operating at a duty cycle of only 1/250. It is then necessary, however, to launch enough satellites to provide continuous coverage. Such a system is not likely to be affordable. A bistatic space-based arrangement with transmitter and receiver separated may provide some relief. The receiver can be composed of a distributed constellation to construct an instantaneous synthetic aperture.

2. Space Applications Volume
3. The fundamental equation of RADAR shows that the detected signal is inversely proportional to the fourth power of the distance, R, to the target. It is this strong dependence on distance that severely limits the range of a RADAR system.
4. Sec. 2.2 of this chapter

A detailed design of a bistatic system may point the way to cost savings, but the prospects are not encouraging for the next decade. The Uninhabited Reconnaissance Aerial Vehicle (URAV) appears to be the most cost effective vehicle.

Observe that 10 meter resolution does not restrict location to 10 meters. Centroid location is a question of signal-to-noise, and there is no reason that centroid location cannot be done to 2-3 meters. Thus, lower spatial image resolution can be coupled with precision targeting. If the target can be identified with a low resolution hyperspectral imaging system, the aimpoint can be located to approximately 2 meters. It appears that, if preliminary experiments are verified, the 10 meter hyperspectral system will provide a global observation system which is affordable and effective. We have defined the following space based system to provide maximum affordable coverage world-wide:

1. Continuous multi-spectral observation at 10 meter resolution with 2-3 meter targeting
2. Continuous location and targeting of RF emitters to 10 meters
3. SAR with 1 meter resolution once per hour
4. Sub-meter resolution once per day, multispectral and SAR

2.2 Standoff Systems

The systems described in Sec. 2.1 are non-intrusive. At the next level of involvement other possibilities arise. If it is possible to position vehicles within 200-300 nm of a region of interest,

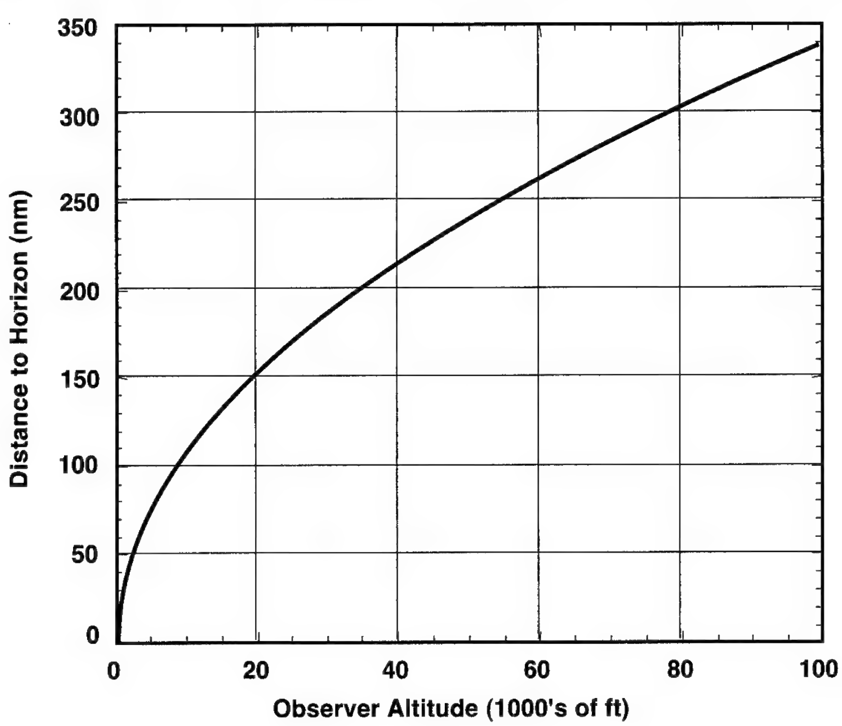


Figure II-2

high resolution staring sensors and SAR's can be carried on URAVs that loiter at 50,000-100,000 feet. Figure II-2 shows range to the horizon from a given altitude.

Continuous monitoring at a resolution of one meter or less is possible. URAVs can work cooperatively with satellite constellations by projecting high power RF beams over the area of interest. The satellites receive reflected signals from targets near the earth to form a distributed bistatic synthetic aperture radar system. Clutter rejection is improved because of the varying reflection angles to different satellites. Moving and fixed targets can be detected with high resolution as the result of the long baseline between satellites. This arrangement limits the number of expensive spaceborne transmitters by restricting coverage to a region of interest. We have added:

5. Continuous Multispectral and SAR observation at 1 meter resolution
6. Continuous bistatic detection and tracking of fixed and moving targets over a limited area

2.3 Overhead URAV Systems

Further improvement in resolution can be obtained in situations where overflight of enemy territory is authorized. Low observable URAVs can carry staring and scanning sensors which produce multispectral and SAR images and LIDAR returns at few centimeter resolution. The URAVs can deploy low altitude or ground based chemical sensors for accurate discrimination of Chemical & Biological (CB) agents and the effluents from Chemical, Biological, and Nuclear (CBN) manufacturing plants. These sensors can be interrogated by driving readout with an RF or optical signal from a satellite or a URAV. The remotely read sensor will have reduced size, weight, power, and vulnerability. Now, the system consists of:

7. Continuous multispectral and SAR observation at 1 centimeter resolution
8. Contact sensors for CBN detection.

2.4 Unattended Ground Sensors

We mentioned the integration of ground sensors into the Global Awareness network as CBN detectors, but a few specific observations should be made. Unattended ground sensors are at present difficult to deploy and to monitor. Deployment by manned intrusion, air or ground, is the norm.[5] It is not clear that deployment and operation are Air Force missions. Technologies now under development and the need for detailed awareness in specific areas of the world can change the situation completely. In addition to CBN detectors, ground sensors are natural candidates to monitor the local weather. *Weather monitoring from space is possible, but ground monitoring can be more accurate, more continuous, and far less expensive.*

Ground sensors can be deployed by miniature UAV's carried aboard larger UAV's. Microsensor development is proceeding, and, as noted, novel readout methods which have a low probability of intercept (LPI) have been proposed. *The Air Force should investigate the advantages of ground sensors for local monitoring before committing to more expensive space and airborne sensors.*

5. Sensors Volume

2.5 Practical Considerations

It is in the region where friendly and enemy airspace meet that the AWACS and Joint Surveillance, Target Attack Radar System (Joint STARS) systems will begin to participate. These systems will continue to be very valuable for the next decade, but it is now time to consider the next generation. Some of the functions of these systems can be implemented in space, but for continuous coverage aircraft, deployment appears to be more practical. The $1/R^4$ factor in the radar equation exacts great concessions from a space based system. The geometric factor and the limited power from the satellite power bus will limit coverage area severely. The deployment of airborne transmitters and satellite receivers in a bistatic geometry as described above is possible, and this may be the ultimate system. After a decade from now, URAV deployment is likely to be the method of choice, although there is a long term possibility for shifting the balance of continuous surveillance completely back to space. It has been proposed that very large, lightweight structures can be deployed in space to create optics and antennas having dimensions of kilometers.[6] It is the product of power and aperture that determines signal-to-noise, all other factors being equal. The URAV and space options are attractive as replacements for AWACS and Joint STARS. Both the AWACS and the Joint STARS use much of their volume for crew and displays, and loiter time is restricted by fuel consumption and crew limits. The systems of the early 21st century should use high speed processors which will exceed current performance by a factor of 10,000 for AWACS and 1000 for Joint STARS. Processor volume should be no more than 1 m^3. Communication rates of 100 MHz to satellites will be practical almost immediately, and lasercom will appear in a decade. Multiple URAVs can detect and process signals coherently to provide large increases in resolution, and loiter times of tens of hours without refueling are possible.

It is unlikely, of course, that the entire collection of sensors would be deployed simultaneously in a single area of interest. The arrival of higher resolution systems can free the lower resolution systems for use at the periphery of the area of interest.

These systems offer the possibility of monitoring the entire world continuously at reasonably high resolution. By now, the reader has realized that the data rate may be impossibly high. Consider that the actual information content from a 10 m system is one bit per pixel spatial and 100 bits spectral. Both SAR and visible images assume that the total information content is 100 bits/pixel over the entire world once per hour. The data rate is approximately 40 GBits/s continuously. If we observe one percent of the world, $1.3X10^6$ km^2, at a rate of once per second the data rate is $1.3X10^{12}$ /s (1.3 TB/s). State of the art for a single optical fiber is 40 GB/s, and 1.3 TB/s necessitates only 40 fibers. In 10-20 years laser cross- and down-links will be capable of these rates, too. The important issues, however, are: Why would one want so much information? Who would look at it? How much would be stored? How would it be analyzed? The possible is not necessarily the sensible.

Surveillance of all of Iraq at a rate of once per hour would produce a data stream of only 85 MB/s, and once per minute would require 5 GB/s. More reasonable problems produce more reasonable communication rates. Certainly, these rates are not out of the question today, and they will be delivered routinely in a decade.

6. Space Applications Volume

Satellite numbers are given in the Panel volumes.[7] We mention number here because it is connected to significant issues of cost and commercial involvement. There are many factors involved in determining the satellite number, but the range will be 100-300 satellites. These numbers are similar to those of the Iridium or Teledesic systems, because the coverage considerations are also similar. The 10 m resolution chosen for the distributed system is also consistent with the size of the commercial satellites. In fact, it may be possible to install passive multispectral sensors on the commercial satellites and to share satellites and communication systems. Ownership of satellite systems by multinational corporations may make sharing undesirable from both the US Government and from the corporation points of view. It may be possible, however, to buy standard satellites from the commercial organizations and to modify them for military purposes. *We estimate the cost of modification for an independent military system to be $10-20M per satellite. Active sensors are more expensive but they will be fewer. For launch costs of $10,000/kg, the weight should be kept below 100 kg to make deployment cost effective.*

2.6 Dissemination of Information

So far we have discussed the part of Global Awareness related to learning about an adversary or about a situation. We have also described it mostly in terms of sensors. There is much more to it than that. We must have a perfect picture of our own and allied forces as well. The picture should include aircraft maintenance status, crew health and availability in addition to location and mission status. The mass of data associated with our own forces is large, but it can be organized by common agreement. It is probable that each Service will configure its databases and information systems in a unique way, and it is certain that our allies will do so. *There is no reason for the differences to limit system effectiveness, but a generic capability to operate across dissimilar networks will be essential.*

Another class of information is essential to Global Awareness. That is information derived from the databases of the adversary. Techniques for mapping and penetrating the military and commercial systems of the enemy are needed. The penetration of enemy databases will, frequently, be more valuable than destroying a Command, Control, Communications, Computers, and Intelligence (C4I) system for obvious reasons. The inverse of penetrating enemy systems is protecting our own. As we become more dependent on integrated information systems we must protect them vigorously. *The Air Force must develop protection technologies.*[8]

We have discussed the collection of data. It has been shown that the communication of data to analysis stations is within the state of the art. The information will be processed and correlated at a few centers . This is not a trivial problem, but we know how to solve it. *Analysis and correlation of data must be done across databases having thousands of variables.*

The final action is the transmission of appropriate information to the nodes which need it.[9] Transmission and request must be done in both directions from operational nodes to information centers and from node to node. There is a growing tendency to demand wide area broadcast of information. Broadcast will be of use while ground based fiber networks are not available and where only a few geosynchronous satellite channels can be used. Broadcast will be useful

7. Space Technology Volume
8. Information Applications Volume
9. Ibid

in the near future when the total volume of sensor data is small, but the amount of information increases, broadcasts will become cluttered or will contain many frames. The full internetting of nodes will enable each node to construct data flow and presentations which satisfy the unique needs of that node. Broadcast of information tends to generate specialized transmission and receiver systems which can be of limited utility. The need for broadcast rather than unique presentation to each node should be verified carefully. It is certainly true that Direct Broadcast Television (DBTV) has become a commercial product with 100 channel capability in a ground station which sells for less than $1000. Most of the cost, of course, is in the space segment and in the generation of programming. *Information broadcast in the DBTV mode will be an important interim capability, but eventually it should be integrated into an "information on demand" system.*

2.7 A Necessary Adjunct System

Almost all of the processes related to Global Awareness need precise and absolute positioning and timing. The most reliable and the least expensive way to provide it is through a space based Global Positioning System (GPS). As the precision of all operations increases, so must that of GPS. *We strongly suggest that the Air Force develop a system that has 30 cm spatial accuracy and 1 ns timing accuracy.*[10] All services are now dependent on GPS, and as that dependence grows, and it will, protection of GPS capability is essential. The receiver enhancement methods now proposed will not be completely adequate as the capabilities of our enemies grow. The satellites and codes must be redesigned to provide both adequate performance and adequate protection.[11] *Code chip rate can be increased by a factor of ten, and signal power can be increased by a factor of 100 to give an improvement in jamming protection of 30 dB.*

2.8 Databases

The concept of Global Awareness is a complex one. Much of the information which is needed to construct the global picture exists today in computers somewhere. *The problems of the next decade are to identify the relevant databases, to devise methods for collecting, analyzing, and correlating them, and to construct the needed communication and distribution architectures.*

2.9 Strategy

The summary of Global Awareness is an extended one. We justify the length by noting that it is here that the commercial interface is likely to be most extensive. *Close attention must be paid to the use and optimization of commercial information, satellite, and space launch capabilities.* This task is not a familiar one to the Air Force. It involves major changes in the ways needs are interpreted and in the ways that systems are designed, procured, and discarded.

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10. Space Technology Volume
11. Munitions Volume

3.0 Dynamic Planning and Execution Control

3.1 Planning and Simulation

Dynamic Planning and Execution Control exploits the information derived through Global Awareness. It is not possible to increase the tempo of operations without increasing the tempo of planning.[12] Planning time should be reduced from days to hours or even minutes. Joint planning will be essential. Reduction of planning time also reduces the time available for review and checking of plans, and the burden of verifying accuracy and effectiveness must shift to automatic systems. Verification of plans will be done by the continuous simulations of the plans using current information about all forces. Consistency checks should be part of all planning and command systems. Displays and planning tools will permit commanders to compare simulations and plans, and to change both easily and consistently. People and databases involved in the Planning and Control process may be separated by thousands of miles. The system will support collaboration through virtual meeting facilities.

3.2 Execution Control

We refer to Execution Control rather than Battle Management as a way of emphasizing that planning and control systems should integrate Mobility and Attack planning in both war and peace. Mobility resources are at least as limited as combat resources,[13] and supply and use of supplies must be coordinated at the same rate as combat operations. Resources used to provide Global Awareness must be integrated into the Execution Control system to supply the information needed for planning and execution at the rate needed to support mobility and combat operations. In an integrated force, the tempo of operations can be no faster than the cycle time of the slowest component of the system. It may be necessary to automate the interpretation of voice commands[14] and responses and to provide automatic translation from one language to another.[15] Although automatic translation may appear to be a distant dream, one should realize that many situations use highly stylized language which should be amenable to machine interpretation and translation.

We should not concentrate solely on producing plans and execution orders at the highest possible rate. The planning and simulation facilities should provide long range estimates at all times. For example, the procurement of a replacement part and its shipment to the point of use may require days. A long range estimate of parts requirements should be produced days ahead of a projected use time. Building munition stocks requires time, but overbuilding stocks is an improper use of mobility resources. This does not mean that long-term plans will not change from, even, hour to hour, but estimates should be consistent and reasonably constant. The automatic systems should be aware of "commitment" times after which changes cannot be made. It is apparent that the execution control system will use expert system technologies extensively.

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12. Attack Volume
13. Mobility Volume
14. Information Technology Volume
15. Human Systems/Biotechnology Volume

3.3 Processors and Communications

The computer and communication systems which are needed can be defined in a straightforward way.[16] The Air Force should be prepared to procure high speed parallel computing systems to make the Dynamic Planning and Execution Control system work. Parallel computing over networks is well along in development and will be perfected by the commercial world. The Air Force should take advantage of these developments. Distributed satellite systems, partly or wholly commercial, are a natural way to provide affordable connectivity where fiber is nonexistent. We depend more and more on commercial terrestrial communications networks, because they are redundant, reliable, survivable, and cost effective. We seem to insist, however, on developing military satcom systems in spite of their exorbitant cost and limited performance. During the next decade commercial satcom systems will exceed the capacity and reliability, if not the survivability, of the military systems. Commercial systems will have multiple ground stations which connect to the worldwide fiber system. They will eventually use laser crosslinks and downlinks that will dramatically increase redundancy of the systems. It is likely that the commercial systems, or DoD-owned commercial-like systems, can be used for military purposes more reliably than can completely unique military systems. This will be especially true if other nations develop anti-satellite systems. *The Air Force should consider carefully before investing further in dedicated military satcom systems.*

Digital communications to and from aircraft will be an important aspect of future warfighting. Links of interest include those for one-way broadcast and two-way command and control. For one-way broadcast, adoption of civilian satellite technology is an interim solution which will enable cheap one-way reception of information on a theater-wide basis. Such a wide-area broadcast service would permit all aircraft to receive critical warning messages, weather, and real time surveillance regardless of their location in the theater.

Two-way links for high performance aircraft, whether to satellites, URAVs, or large aircraft, continue to present a challenge. Current systems (low cost modems and higher cost JTIDS) already permit digital links to fighters. Wide area networks can be established through use of gateways on URAVs or large aircraft (such as the Joint STARS or AWACS). Figure II-3 shows the line of sight range between a relay transmitter and a fighter for various altitudes. A URAV at 60,000 feet can transmit line of sight to a fighter at 20,000 feet over a range of more than 400 nm. We recommend that technologies appropriate for direct satellite links to fighters be explored, but the Air Force should continuously evaluate the cost and utility of direct satellite links compared to links through aircraft.

Direct Satellite link to large aircraft and to URAVs is a much simpler and less expensive option. Certainly direct satellite links should be provided to all airlifters, AWACS, Joint STARS, URAVs and tankers. Commercial carriers will probably suffice for the airlifter links and, perhaps, for the tanker links.

16. Information Applications Volume

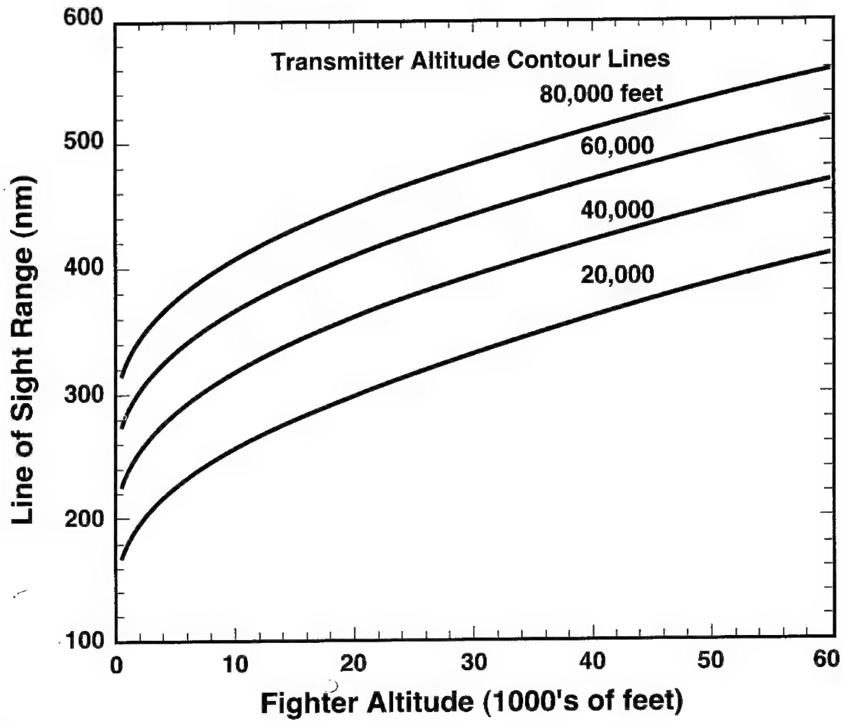

Figure II-3

3.4 User and Developer Interactions

The interaction of users with all systems must be flexible, secure, and situation dependent. Intelligent Agents[17] can be developed to support the interaction. Flexible connectivity can be achieved with commercial operating systems, network protocols, and programming languages. Some argue that only unique military operating systems and government standardization of equipment and protocols can guarantee security. Exactly the opposite is likely to be the case. Creation of a single unique universe increases the probability of a single point failure which can destroy the entire system. The folly of that logic was recognized millions of years ago in biological evolution, because the absence of biological diversity in a species makes the entire species susceptible to a single virus. The Air Force must beware the natural human tendency toward absolute standardization.

It will be necessary to develop security and priority systems which overlay or integrate into commercial systems such as UNIX, the Internet, and C++. These additions should be constructed such that commercial software development tools can be used. The Air Force should not be in the software tool business. Nor should the Air Force be in the computer language and compiler development business. A capability for the use of Ada should be maintained for special cases where it is appropriate. In general, however, Ada has become irrelevant in the information world. Other languages are developing much faster. Insistence upon its use increases

17. Information Technology Volume

cost and development time of systems and reduces the availability of commercial software and tools. It is time that the use of arcane languages such as Ada be relegated to situations where nothing else will suffice.

3.5 Caveats

We have suggested what to do, but it is as important to say what not to do. At all cost the Dynamic Planning and Execution Control System must not be planned as a closed, finished product. If it is to utilize rapidly developing technologies it must be open ended. It should be a growing organism which incorporates advances naturally and gradually. *The Air Force must avoid designs which demand permanent adherence to particular hardware, languages, or operating systems.*

An organic, growing system can be planned and built one section at a time. It is now time to get on with it.

4.0 Global Mobility in War and Peace

Mobility can be the limiting factor in operations. Airlift is also in demand during peacetime for humanitarian operations. Humanitarian operations bring special problems to the Air Force, because they may require airlift aircraft and people to enter regions of high danger. It may not be possible to provide external protection for airlifters or external response to attack. The safety of mobility operations will be increased greatly by Global Awareness and by Dynamic Planning and Execution Control. The Air Force airlift system will be integrated into both systems. Today, it is technologically possible to track shipments and aircraft in real time at reasonable cost. New commercial satellite systems, such as Iridium, can be used to enhance that capability at lower cost and higher reliability.

Airlift is the only transportation mode which can respond to a crisis worldwide in days. The capacity of the system planned for the next two decades is less than that required to support existing forces,[18] even with the addition of the Civil Reserve Air Fleet (CRAF). Airlift capacity depends on storage areas, cargo handling equipment, refueling facilities, and airport capacity as well as on aircraft. Reduction in cargo handling equipment, which includes Army supply trucks, increases capacity, because that equipment is frequently delivered by airlift. We need to improve the efficiency of both aircraft and of delivery methods.

We should search for mobility improvements which are not related to increasing the number of carriers. The capacity of the mobility system depends on lift capability and velocity of the carriers. It is unlikely that the speed of ships, trucks, or aircraft will increase significantly during the next three decades for the bulk of delivered cargo. It is possible to increase the size of vehicles by 50, or even 100 percent, but cost per unit mass delivered will not decrease by as much. Therefore, we seek technologies which reduce the time enroute by other methods and which reduce the amount of materiel needed.

18. Army Science Board 1994 Summer Study - *Capabilities Needed to Counter Current and Evolving Threats*, April 1995

4.1 Future Airlifters

Worldwide coverage will require aircraft that can fly 12,000 miles, deliver cargo, and return without refueling at the terminal point. Air refueling is a logistics intensive operation, and airlifter refueling can be eliminated. Cargo capacity for airlifters of the 21st century should be 150,000 pounds. With improvements in aircraft and delivery methods, the gross takeoff weight will be 1,000,000 pounds.[19]

First the aircraft. Aircraft such as the C-17 or the B777 are impressive airplanes that outperform their predecessors. They are, however, evolutionary improvements over earlier designs. We asked whether there are aircraft technologies that could give much better performance. The answer was -- yes.[20] The technology lever appears to be large improvement in lift to drag (L/D) ratio of a wing coupled to evolutionary improvement in engines. We examined the Wing in Ground Effect (WIG) as a possibility. Improvements of 20 percent appear possible at altitudes of 0.1 times the wingspan, but there are many drawbacks in the WIG system. It operates at altitudes of a few feet and is restricted to over water transport. We then asked whether there are improvements possible to wings operating out of ground effect. Again, the answer was -- yes. It has been observed that high L/D wings have high aspect ratio. For heavy loads, the wings become quite long and they twist. If the twisting effect can be eliminated, the efficiency of the wing can be increased significantly. A possibility which has been investigated is to add a second fuselage.[21] Calculations indicate that a 40 percent increase in aircraft efficiency can be obtained. The drawback of this system is that wider runways and larger parking areas are needed. Ultimately, new materials should add adequate stiffness to a wing without increasing weight.[22] *In general, it appears that wing research could pay off in significantly higher aircraft efficiencies.*

Engines are undergoing noticeable, if evolutionary, improvements, too. Efficiency increases of 20 percent should be realized during the next decade or two.[23] Significant increases in engine efficiency may be possible through applications of modern adaptive control methods to engines. Fast response controls can reduce the operating margin now reserved to provide protection against engine surges. Improvements of 10 percent appear possible. Further improvements of a few percent may be achieved by using magnetic or air bearings rather than mechanical bearings.

4.2 All-Weather Operation

An improvement that could increase delivery rates substantially in many parts of the world is all weather operation. Auto landing (Category III) using differential GPS and the civil Clear Access (C/A) codes has been demonstrated. The GPS autoland system can also guide the aircraft during taxi in zero-zero conditions (Category IIIc). A wide area differential system, which does not require nearby ground stations has been proposed and demonstrated through the Joint Direct Attack Munition (JDAM) program. Accuracy of 30 cm has been demonstrated. This capability will enable autoland and "blind" taxi anywhere in the world without the addition of equipment on the ground. Installing this capability in airlifters should certainly be a high

19. Mobility Volume
20. Aircraft and Propulsion Volume
21. Mobility Volume
22. Materials Volume
23. Aircraft and Propulsion Volume

priority. Commercial equipment can be used extensively to construct the wide area differential system. Jamming resistance is not improved by the differential system. Its primary advantage is that it can be done now. *It should be done immediately.*

4.3 Point-of-Use Delivery

Next -- delivery methods. An item shipped by military airlift from one point to another will usually spend more time on the ground than in the air during the shipping process. Technology can help to reduce the ground time by providing planning and scheduling of delivery and distribution as mentioned earlier. Efficient planning coupled with real time simulation can help one make the most efficient use of facilities and equipment. It cannot, however, compensate completely for too few cargo handling devices, too little ramp space at receiving airports, diversions because of weather, or damage resulting from enemy attack. If we attempt to deliver to austere runways near a combat area, we place airlifters in danger. Even in peacetime, such as now in Bosnia, delivery is sometimes canceled because of dangerous conditions during landing and takeoff. Bosnia is also an example of a theater where point-of-delivery and point-of-use are separated by hostile territory.

The technologies needed for evolutionary improvements which will enhance capacity are clear. For example, in addition to the planning and execution improvements noted above they include improvements in onboard and offboard handling equipment. We sought ideas that could provide more substantial improvements in delivery rate. The one we have chosen to describe in detail is "point-of-use delivery". The purpose of point-of-use delivery is to reverse the ratio of cargo ground time to cargo air time. Approach and landing delays will be eliminated. All weather operation will be possible. If cargo can be delivered directly to the user, airport bottlenecks will be eliminated. Secondary benefits will further increase delivery rate. Many of the K-loaders that unload the aircraft will not be needed. Many of the trucks that carry cargo from airport to user will not be needed. The warehouses that store cargo waiting for user pickup will not be needed. Some airports will not be needed. The amount of cargo handling equipment delivered by airlift will be reduced, and the space can be used for cargo. Land transport through enemy territory will be avoided. Cargo density on the ground will, of necessity, be lower than in storage areas, but average delivery density can be higher than on an airport.

If point-of-use delivery can become routine, the effect on Army operations will be profound. This is a truly revolutionary capability. It will be impossible for an Army unit to outrun its supply train. Mobility and maneuver flexibility will be that of the fighting unit rather than that of the supply unit. Supplies will be delivered by large airlifters rather than by truck or helicopter. Possibilities for enhancing maneuver effectiveness are nearly endless. Point-of-use delivery is more than precision airdrop, although it includes precision airdrop. The problems:

- Deliver cargo without landing the aircraft to an accuracy of 10-20 meters from altitudes up to at least 20,000 feet.
- Load aircraft with cargo and drop equipment at the same efficiency as for land delivery.
- Extract cargo in random order.
- Recover and reuse drop equipment unless cost per drop unit is negligible.

At present airdrop is an emergency procedure. Accuracy is poor. Two methods have addressed the problem of improving accuracy. One is to measure wind profile with a LIDAR[24] or a GPS dropsonde and to compute a release point (CARP) based on the wind. The accuracy of this method is limited to 100 meters by parachute reproducibility and measurement accuracy. The second method uses a large, steerable parafoil with GPS based guidance. Both the parafoil and the control system are expensive, and the cargo lands with high forward velocity. A combination of the methods where the parafoil is replaced with a much lower cost system may be effective and affordable. Standard, non-steerable parachutes exhibit forward motion at a few knots. If wind measurements can be made, the forward or "drive" velocity will be adequate to compensate for wind measurement errors. The system can be steered by a GPS controlled steering system on the load. Load mounted steering will permit the use of balanced aerodynamic forces, or trim tabs, and the guidance power will be greatly reduced. A "de-reefing" system deployed at an altitude of a few feet will effect a soft landing with acceleration comparable to forklift handling. The cost of the entire system should be a factor of ten cheaper than currently proposed precision systems. Recovery of equipment can be done by air pickup, an area in which we have much experience. Precision release is an integral part of an airdrop system, but little work has been done in this area. Immediate improvement can be made over the archaic system now used. *In the future, the problem of airdrop should be treated as seriously as the problem of bomb drop*. For example, airlifters equipped with belly doors could deploy cargo randomly, and release precision could be much higher than for deployment through rear doors. *Future airlifters should be designed for point-of-use delivery.* Existing airlift aircraft have all been designed for air-land delivery. An airlifter designed for point-of-use delivery will be quite different.

The question of how to deliver personnel should not be ignored, but we admit to having no completely new ideas. Airdrop of personnel in individual parachutes is inefficient and dangerous. The density of troops on the ground is low, and there is an extended period of vulnerability after landing. There is no reason that personnel could not be dropped in containers using the same equipment as described above for cargo if accuracy and safety can be guaranteed. Personnel drop vehicles could be armored with lightweight armor of the type now used on airlifters. Rather than carrying all equipment on the soldier's body, arms and supplies could be carried in holders onboard the delivery vehicle.

4.4 Special Operations

A comment about delivery of Special Forces is in order. This subject has been studied many times, and Vertical Takeoff and Landing (VTOL) aircraft are being produced. We observe that while a few VTOL aircraft will, undoubtedly, be very useful, almost all missions can be completed with Short Takeoff and Landing (STOL) aircraft which have takeoff and landing distances of 100 meters or less. Engine power required is 50% less than for VTOL aircraft, and range and payload can be far higher for a given aircraft size and weight. A Short Takeoff and Vertical Landing (STOVL) aircraft can increase flexibility even more without large increases in weight or cost.

24. Mobility Volume

4.5 Aircraft Protection

Point-of-use delivery may place airlifters in locations where the threat level is higher than those now encountered. At least, though, the airlifter operates at high altitude, and the time available to respond to a threat will be longer than for an aircraft on approach or climbout at an airport. Airlifters should be equipped with a self protection suite which includes the following three capabilities (only the third requires development):

- ECM protection against radar seeking and RF command guided missiles.
- Fighter protection against other airborne threats, such as guns.
- Laser, High Power Microwave (HPM), or kinetic energy missile-killing systems against IR guided missiles, including focal plane arrays.[25]

5.0 Projection of Lethal and Sublethal Power

The Air Force understands well the issues associated with projecting power from airborne platforms. The subject of Precision Guided Munitions (PGMs) and their benefits needs no elaboration. We do, however, present ideas for making PGMs more effective. We will discuss power projection methods and devices which are different from those now in use. The Global Awareness and Dynamic Control capabilities will enable power projection capabilities not now possible in both existing and new platforms. Many of the fundamental tasks presented to the Air Force will not change much during the next decade. Added to the traditional air-to-air and air-to-ground missions, however, will be the countering and destroying of weapons of mass destruction and operations in urban areas. It is likely, too, that the availability of low cost SAM's will establish a premium for the their efficient destruction.

It is intellectually satisfying to discuss power projection in the abstract, and the technologist will frequently promote new and effective weapons without reference to their specific use. Such discussions are important, but they are usually too general, and they do not motivate the development of specific technologies and systems very well. We have discussed the control inputs to power projection in the sections on Global Awareness and on Dynamic Planning and Execution Control. These capabilities also provide target type and location. Here we will address the reasons and methods for projecting power. A more detailed discussion can be found in the Attack Panel Volume.[26]

The Air Force must project power globally. The methods by which this is done will vary depending on whether the nearest bases to the targets are within the range of fighter aircraft or not. In the worst case, only bases in the CONUS will be available. We expect situations to be more varied in the future than they were in the past. This statement is partly based on assessment of current world politics and partly on our ignorance of the future. In particular, we may execute more missions over "mixed" territory where the distinction between ally and enemy is blurred. We may also expect more operations in urban areas.

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25. SAB Study - *Aircraft Self Protection Against IR Seeking Missiles,* Phase II, December 1994
26. Attack Volume

5.1 Aircraft and Systems for Power Projection.

We explored the enhancement of existing aircraft and weapon systems during the study on *Life Extension and Mission Enhancement for Air Force Aircraft.*[27] The study identified avionics and training as the highest leverage technologies for improving the capabilities of the existing fleet. Those suggestions are appropriate for integrating the current fleet into the capabilities described in this report. Here we describe the justification of the Uninhabited Combat Air Vehicle (UCAV).

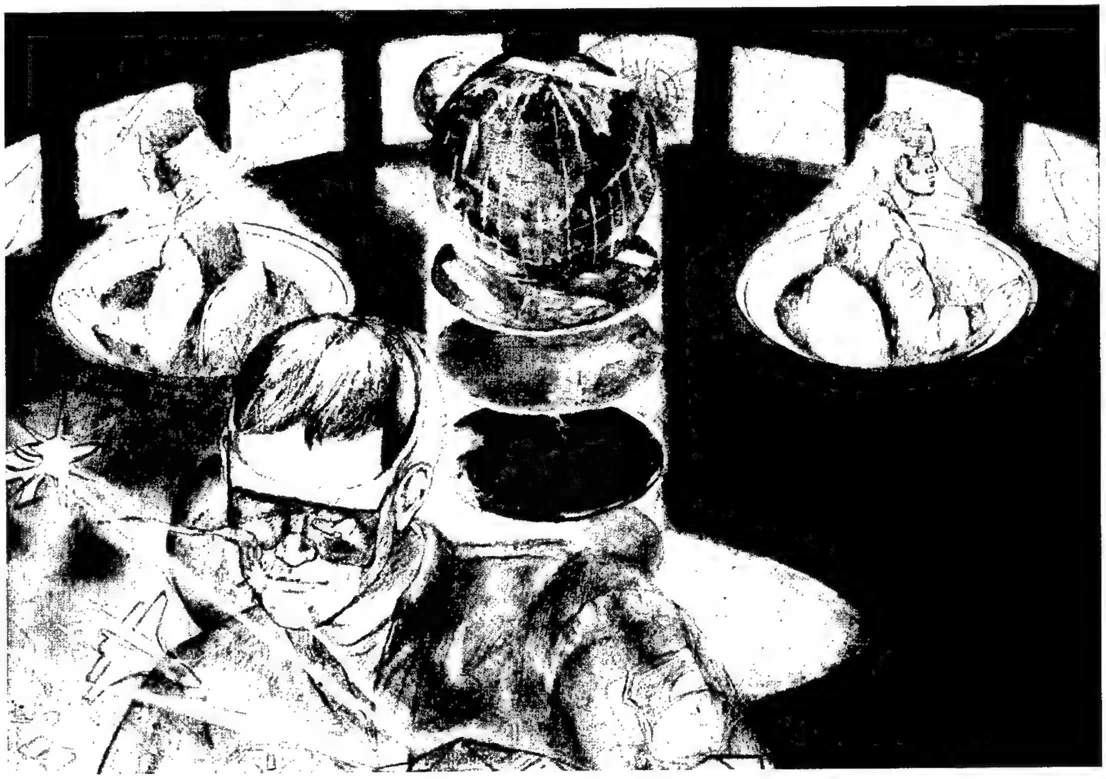
5.1.1 UCAV

An effective UCAV will be enabled in the next century as the result of the simultaneous optimization of information flow, aircraft performance, and mission effectiveness. The UCAV will not completely replace the inhabited aircraft for decades, if ever, but the presence, or absence, of a pilot is now a design trade that can be made in a logical way.

It is the improvements in sensors, processors, and information networks which make the UCAV possible. Information will increasingly be derived from sensors outside the air vehicle itself. Current concepts call for transmitting information derived from many sources over a satellite or ground-based link to the pilot of a high performance combat aircraft. The amount of information which can be injected into the cockpit is enormous. Discussion of pilot overload is common. More displays are needed in an already crowded cockpit, and more attention is demanded from an already overworked pilot. The question which must be asked, then, is whether it is more efficient to bring the pilot to the information rather than to bring the information to the pilot. The usual UAV issues, such as survivability, are secondary if performance is not compromised. When one considers the volume of information which will be necessary to conduct precision, high intensity operations of the future, it is possible that the most economical use of communication resources will be to transmit low bandwidth control, or control correction, information to the aircraft rather than to transmit mission information. The decision to use UCAVs will, of course, depend on the theater environment which has many variables such as the density of enemy jammers.

Information gathered from many sources, included from the UCAV, itself, will be brought to the Execution Control Center, which is located in the US, over high speed, massively redundant fiber and satellite communication routes. A permanent environmentally controlled installation will permit extensive use of state-of-the-art commercial equipment. Vehicle cost and weight will be reduced because of the absence of displays, pilot life support equipment, and manual controls. Volume, area, and weight of displays, processors, and controls in the Control Center can be large. Well rested mission specialists will be available to provide support for one or more UCAVs, and a cadre of expert, possibly civilian, maintenance technicians will also be available. The number of support personnel in the theater will be reduced, and it will not be necessary to transport a large number of shelters, workstations, and environmental control units. Extremely low observability of the UCAV will result in the reduction of standoff distance at the weapon release point and will, in turn, reduce weapon sensor, guidance, and propulsion costs.

27. SAB Summer Study 1994, *Life Extension and Mission Enhancement for Air Force Aircraft,* August 1994



UCAV Control Center

Control technologies for UCAVs are not mature. The interaction between airframe and pilot will be cooperative and variable to a much greater extent than in existing aircraft. The pilot(s) will provide general direction in realtime when necessary. Control functions will be enabled by software agents transmitted from the Control Center. Agents will permit function changes such as from ground attack to air defense during a mission. Unplanned maneuvers can be generated in realtime.

UCAV survivability can be increased by increasing maneuverability beyond that which can be tolerated by a human pilot. Acceleration limits for inhabited aircraft are, typically, +9 g or 10 g and -3 g. A UCAV can be designed symmetrically to accelerate in any direction immediately. Anti-aircraft missiles are usually designed with a factor of three margin in lateral acceleration over that of the target aircraft, although a few missiles have acceleration capability as high as 80 g. A UCAV with a ±10 g capability could outfly many missiles, and an acceleration capability of ±20 g will make the UCAV superior to nearly all missiles.

Removal of the pilot from the aircraft also makes possible more options for signature suppression. Inhabited aircraft have limited options of shape and cross sectional area which limit the options for minimizing drag and radar cross section. Maneuvers and flight attitudes not appropriate for inhabited aircraft can also be executed to reduce the cross section presented to an adversary. The UCAV will also provide design flexibility for active stealth systems when they are developed.

The Air Force should pursue the design of a UCAV. It appears logical to begin with cruise missile parameters such as those of the Advanced Cruise Missile and then to increase capabilities by scaling. The inverse procedure of scaling down from an inhabited aircraft, say the F-22, may lead to higher cost and cross section. Operational concepts should be developed, and new weapon options should be pursued. Novel methods to optimize the interaction of remote pilots with a UCAV should be explored through simulation. Control and communication methods should be developed. The point to be made here is that the UCAV is a unique aircraft, and it should be designed as such.

5.2 Critical Tasks

There are a number of tasks which must be accomplished. Particular targets of importance are:

- Aircraft
- Fixed
- Mobile
- Chemical, biological, and nuclear weapons and production facilities
- Urban[28]
- Enemy directed energy weapons
- Short dwell targets
  - Theater ballistic missiles
  - Surface to air missiles
  - Vehicles - armored and unarmored
- Cruise missiles
- National forces
- Terrorist groups
- Concealed
- Personnel
- Protected command centers
- Information systems

We will not address all categories in this chapter, but we will discuss the ones which involve new technologies. It is frequently true that operational considerations dictate the technological philosophy applied to the development of a new weapon system. In the case of

28. Classified Volume - on file at the SAB Office

targeting in the Future Force described in Chapter I, the converse is true. Accuracy, reliability, and cost considerations dictate a discipline of delivering a weapon to a particular set of coordinates using GPS/Inertial guidance, if possible. We realize that it will not always be possible. There will be targets which demand specialized sensors or remote control. Of those two, automated remote control from a precision platform, such as a UCAV, is preferable. We encourage the weapon designer of the 21st century, though, to consider non-coordinate options as a last resort—not as a method of choice. Generic attack tasks for important targets are discussed in the following paragraphs.

5.2.1 Fixed Targets

We define fixed targets as those which remain nearly stationary long enough that they can be struck by a weapon which is directed to a particular set of coordinates. Many types will come to mind. Airbases, storage depots, command centers, and rail yards all fit the description. Not so obvious are parked or very slowly moving vehicles such as missile launchers, SAM, and artillery pieces. A "nearly stationary" target is one whose movement is less than the accuracy of the weapon during the weapon flight time. Targets may be fixed for minutes or permanently. In general, a fixed target is one that is detected by sensors on- or off-board the delivery platform, and the weapon is targeted by coordinates alone. The distinction is useful, because weapons which can be targeted by coordinates alone can have sensors and controls which are far simpler than those needed by weapons which attack moving targets, as mentioned above. In fact, if adequate precision can be obtained in platforms, release mechanisms, and weapon cases, it will be possible to achieve precision munition performance with no sensors onboard the weapon. There appears to be no fundamental physical reason that a weapon released from a high speed aircraft cannot be as accurate as a rifle bullet. Reentry vehicles delivered by Intercontinental Ballistic Missile (ICBM) are at least that accurate. Platforms must be low observable, fast, and designed around the weapons. We believe that the UCAV is the ideal platform for delivery of unguided weapons. Extensive, reusable, (and, therefore, affordable) sensor suites can be aboard the UCAV. A class of fixed targets which will be addressed separately is that of short dwell targets.[29]

Although all fixed targets can be addressed with common sensors, or no sensors, and delivery methods may be very much the same for all, the energy applied to the target may vary considerably with the target type. If sublethal response were in order, High Power RF (HPRF) weapons could be used against vehicles and electronic devices. The deployment of HPRF by cruise missile is discussed in the Munitions Panel Volume.[30] Flexibly fuzed munitions will be the weapon of choice against structures. Area coverage will continue to be provided by multiple small munitions, but we observe that multiple fixed targets do not, necessarily, demand multiple sensors onboard the weapon. However, autonomous precision micro munitions based on low cost electro optical systems may become inexpensive enough to alter the tempo of warfare dramatically. Interdiction will continue to be the most uncertain of operations in terms of weapon requirements for a particular mission, but technology can produce more flexible weapons to increase mission effectiveness.

29. Sec. 5.2.6
30. Munitions Volume

5.2.2 Mobile Targets

Mobile targets deserve particular attention for many reasons. They offer opportunities for technology to increase the effectiveness of air to ground attack. It is more important, though, that a future target set may contain more mobile targets than fixed targets. Critical fixed targets can be nonexistent or prohibited by policy. We have endured both cases in the past. In fact, since World War II, the Gulf War was the only war where nearly all important targets could, in principle, be attacked. Fixed targets of the future may only be those associated with close air support and interdiction.

Mobile targets are special because of the variability of hardness as well as because of their motion. We possess specialized munitions which are nearly as varied as the weapon set, and which have special sensors, special explosive systems, special propulsion systems, and special delivery methods. It is the variability of weapons which makes planning for an interdiction mission much more difficult than planning for other missions. We may point proudly at a large variety of munitions which attack a large variety of targets, but we must remember that in interdiction the cycle time increases, and the sortie rate decreases, with an increasing number of weapon types. The absurd limit of type proliferation prohibits loading of weapons on aircraft until all targets for an interdiction mission are identified precisely. Effective use of camouflage and concealment measures by the enemy will complicate the process even more. Targets of opportunity could be restricted to those which fit the weapons already onboard the aircraft when the target is detected. The immediate solution for the commander, of course, will be to load aircraft with munitions which will destroy the most difficult targets that may be encountered during the mission. These are likely to be the heaviest or the most expensive munitions in the inventory. An alternate strategy is to load specific aircraft with specific weapons. Either strategy reduces overall sortie effectiveness.

Advances in sensor, fuzing, and control technologies offer a partial solution to the problem. Focal plane sensors and low mass, low volume processors can be developed to select the most vulnerable point on a given target, and precision controls can direct the munition to that point. One must think of accuracy in centimeters, not in meters, because advances in these areas are materializing at a rapid rate. Weapon effects can be varied by detonating the munition in various modes. For example, a shaped charge penetrator can be created for armored vehicles, and more uniform blast or fragmentation effects for softer targets can be produced by varying the detonation sequence in a single device.

Cost is a major factor in precision weapons, but commercial developments will reduce component cost. Further cost reductions can be attained by placing most of the processing and sensing functions on the delivery platform and communicating target information to the weapon.

It is often sufficient simply to stop moving targets. Unarmed vehicles can be left immovable. An immobile armed vehicle becomes a fixed target which can be destroyed with simple munitions. Of course, stopping and destroying an aircraft are equivalent processes. HPRF weapons can be effective against vehicle ignition systems and aircraft control systems.

5.2.3 Weapons of Mass Destruction

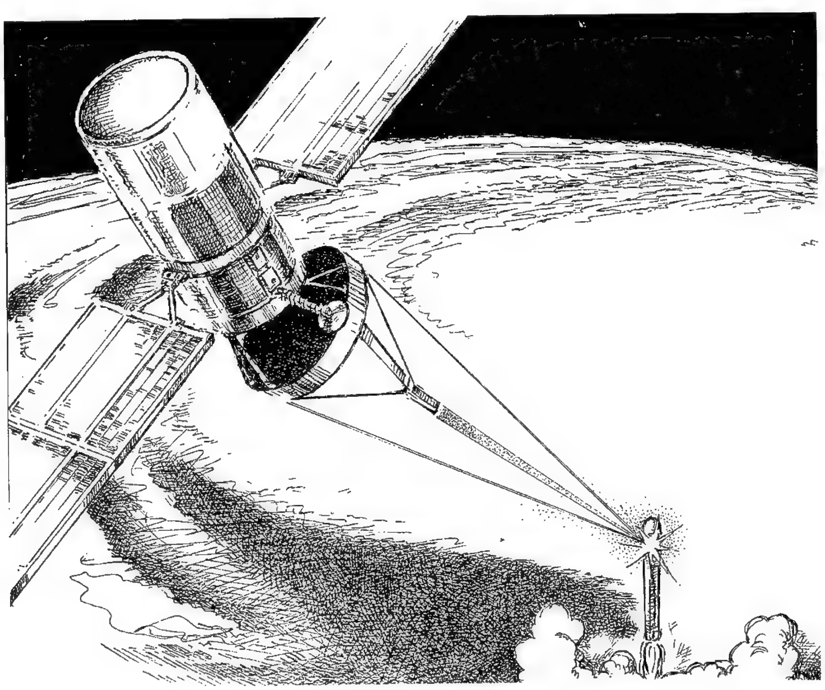
There are no weapons which address all threats. The danger of attacking weapons of mass destruction is in spreading toxic or biological active materials. Therefore, most solutions will immobilize, not destroy, these weapons. Destruction of production facilities will be deferred by isolating facilities and rendering them inaccessible or unusable. An entire stable of advanced precision and directed energy weaponry will be necessary.

5.2.4 Terrorists in Urban Areas

Terrorist operations are usually characterized by the proximity of noncombatants. Hostage situations are possible. These situations are treated at present by special teams using appropriate weapons. Air Force participation is limited to delivery of combat teams and supplies. In the future, however, the development of sublethal weapons deployed from aircraft and URAV sensors will increase Air Force responsibilities in this area. *A weapon which can have a very large impact on urban warfare and hostage situations is discussed in the classified section of the report.*

5.2.5 Directed Energy (DE) Weapons

We have identified directed energy weapons as coming of age. We cannot discount the possibility that an adversary will develop such weapons. It is well known that development of directed energy weapons was well supported in the Soviet Union. The technologies involved may be for sale in the future. Therefore, as we develop these weapons, we should define countermeasures.



Space Based Global Precision Optical Weapon Attack on Boosting Ballistic Missile

Development of hardening standards for probable enemy weapons is the first step. Seekers for lasers and HPRF can be developed. Ranges need only be consistent with the ranges of DE weapons. The sensing problem is not difficult, because of the high intensities involved.

5.2.6 Short Dwell Targets

We define short dwell targets as those that are vulnerable for a time short enough that their vulnerability is determined by the exposure time rather than by characteristics of an attacking weapon. Mobile missile launchers are an example. Launchers can be concealed, camouflaged, or protected by a structure until ready for use. After use they can be moved rapidly to a protected, or concealed, position. It is the protection of the target which distinguishes it from a mobile target.

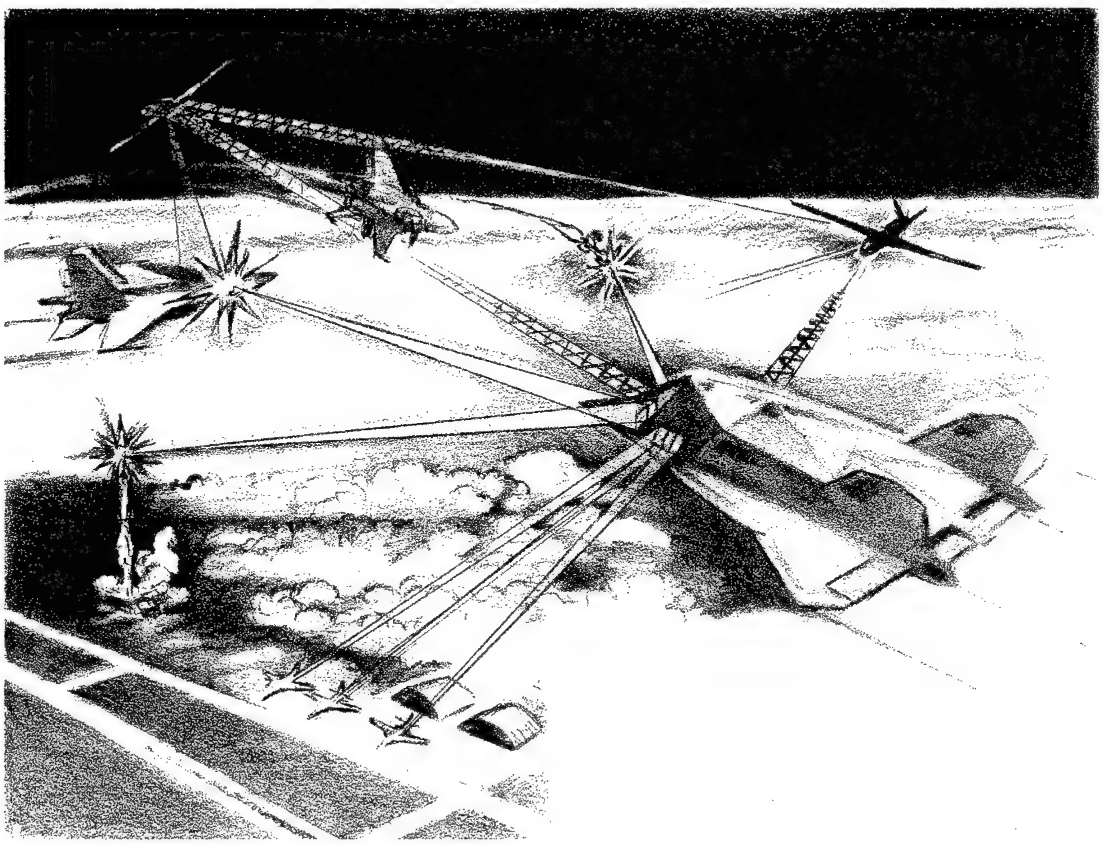
Attack on short dwell targets is enabled by two factors - identification and weapon delivery. The Global Awareness system will detect and identify a target. If there is a URAV staring at the area of interest,[31] the Global Awareness system will deliver target coordinates to an accuracy of one meter or better, and the Dynamic Planning and Execution Control system can target a coordinate-seeking weapon in seconds. Detection by satellite constellation to an accuracy of 2-3 meters is adequate for the deployment of weapons having warheads of 50-100 kg. Targets such as Multiple Launch Rocket Systems (MLRS) and Transporter Erector Launchers (TEL) for theater ballistic missiles will be particularly vulnerable to this weapon system if weapon delivery times are short enough. If observation is by a URAV, an accuracy of 30 cm or less can be obtained, and warheads as small as 0.1-1 kg can be used. These weapons can be carried aboard the URAV. SIGINT detection by a distributed satellite constellation followed by coordinate transfer to a weapon will be extraordinarily effective against SAM sites and other facilities which radiate infrequently.

The best known short dwell target is the theater ballistic missile (TBM). The airborne laser (ABL) is an excellent first attempt to destroy TBM's in boost phase. The program will develop the user database for future applications of lasers as well. We encourage the development of the ABL and associated research to improve capability.[32] The ABL will require a high speed command and control system. Experience in the development of this system will provide a guide for addressing short dwell targets in general in the future.

Short dwell targets of importance are also high value targets. Therefore, a short dwell attack weapon can be useful even if the probability of destroying the target is low, and the cost is high. Attack at considerable distance is usually necessary. Warheads of 100 kg mass can be delivered by a 500 kg missile at a velocity of 2-3 km/s. A target having a 5 minute dwell and a 2 minute targeting time at a range of 400 km can be attacked. This appears to be a reasonable goal for a short dwell attack weapon which will be useful when used with URAV surveillance for the next decade and for a distributed satellite system the decade after that. Affordability is a significant issue. If coordinate targeting is used, a unit cost of $250K-$500K is possible. Other seekers and higher weapon velocities will cost more. Average weapon velocities as high as 4 km/s can be attained, but missile cost may be $1M.

31. Sec. 2.3 and 2.4 of this chapter
32. Directed Energy Volume

The UCAV can be designed as a hypersonic weapon delivery platform. Reusable UCAVs which deliver unguided or coordinate guided weapons may be cost effective when compared to individual missile costs of $1M. For the UCAV, air breathing propulsion or a combination of rocket and air breathing propulsion may be the system of choice. Design and construction of a hypersonic aircraft at 4-5 km/s, Mach 12-15, will be complex and will require new airframe and propulsion technologies. Flight altitudes will range from 25-45 km (85,000-150,000 feet). A hypersonic UCAV will, undoubtedly, be far less expensive than a manned vehicle, and performance will be superior. For example, higher skin temperatures can be tolerated. The vehicle will transition from subsonic to supersonic to hypersonic flight as altitude increases and will transition back to lower speed and altitudes near the target. Velocity transition will obviate the need for a new class of weapons for hypersonic release.[33]



UCAV Fotofighter Attacking Air and Land Targets with High Power Laser Beams

5.2.7 Cruise Missiles

Large numbers of cruise missiles are extant worldwide. The success of the Tomahawk in the Gulf War demonstrated their efficacy to the entire world. We can expect sales and use of

33. Aircraft and Propulsion Volume

cruise missiles to increase during the next decade. Cruise missiles present special problems of detection and destruction. The missiles are small, and they present low radar cross sections. Missiles which fly at high altitude can be attacked as are conventional aircraft. Cruise missiles are slow, vulnerable, and maneuver little. They can be intercepted and destroyed by existing air-to-air missiles.

Low flying missiles are far more difficult to detect than their high flying analogs. The bistatic radar system described in Sec. 2.2 of this chapter is the best candidate for an affordable detection system with wide area coverage. Command guided missiles with IR sensors to provide terminal guidance can be developed. An airborne laser system can intercept and destroy low altitude cruise missiles at a range of a few 10's of kilometers. HPRF systems aboard large aircraft and ground based systems can be effective at similar distances.

5.2.8 Concealed and Camouflaged Targets

Detection is the primary issue associated with these targets. Detection probability will increase as sensor spectral range and number of viewing angles are increased. The Global Awareness system of Sec. 2.0 is well suited to the detection of concealed targets. The spectrum covers RF to optical wavelengths, and multiple viewing angles are provided by the distributed satellite and bistatic radar systems. Emissions are detected by the distributed satellite synthetic aperture signal locating system.[34]

5.2.9 Information Systems

Methods for attacking information systems are under development, and we believe that the technologies being pursued in many areas are appropriate. An important issue to be addressed is the integration of information system attack with the capabilities described in this Chapter. The computer oriented attack methods should be integrated with the Global Awareness and Dynamic Planning and Execution Control systems. For example, techniques developed for locating enemy information systems can be integrated with these systems to permit attack with explosive munitions. Location of threat information systems is also an integral part of Global Awareness. *The entire fabric of Information Warfare should be joined to the fabric of more conventional warfare.*

6.0 Space Operations

Space operations will become increasingly important to the successful completion of most missions in the 21st century.[35] The essential role of Space in Global Awareness and Dynamic Planning and Execution Control was discussed, and, in particular, the value of distributed satellites was addressed. The interaction between military and commercial space applications has not begun to evolve. It is time, now, for the Air Force to define its relationship with commercial and international space organizations. Commercial organizations have used satellites for communications for years. Geosynchronous satellites form an important part of the worldwide communications system, particularly for the relay of one-way broadcasts. For two way communications, fiber is rapidly becoming the medium of choice. Commercial applications

34. Sensors Volume
35. Space Applications Volume

during the next decade will include distributed constellations for cellular communications of voice and data from low power ground transmitters and high resolution imaging systems. The direct use of these systems for military purposes will be cost effective. We must realize, however, that commercial systems will not provide a one-for-one replacement for analogous military systems. The way in which the systems are tasked and the way in which their information is used will require changes in requirements for communication and imaging products.

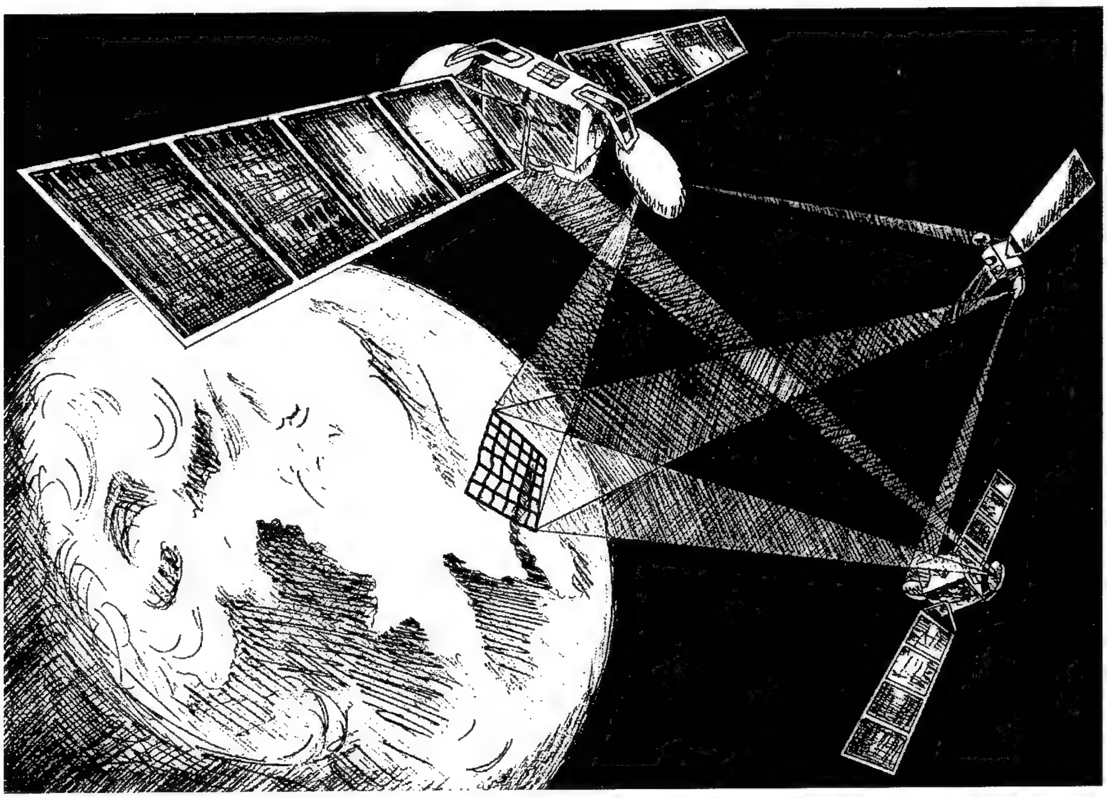
6.1 Distributed Satellites

Affordable use of distributed satellite constellations will require discipline in the design and launch of space vehicles. The launch of a satellite is now an unusual event. Each launch resembles a technology demonstration. It is common for a satellite to contain many unrelated devices solely because volume or launch mass is available. The result is high cost and mass. If lightweight distributed systems are to be of use, this practice must be controlled. Single, or dual purpose satellites must be the rule rather than the exception. If two or more systems coexist on a single satellite, their functions should be complementary. Pressure to include unrelated devices results from excessive cycle time. Cost is also proportional to the time required to design and build a satellite. *Time from design to launch should be reduced substantially. A goal of two years is reasonable.*

Small distributed satellite systems can provide the warfighter with relevant, timely information at a cost below that of large systems. Humans tend to be visually oriented, and we have depended on images to provide us much of what we know about the battlefield. During the past decade, or so, we have learned that imaging outside the visible band, particularly in the infrared, can give us important information beyond that obtained from a visible image. More recently, Synthetic Aperture Radar (SAR) images have begun to contribute important data. The relaxing of image resolution requirements results in smaller sensor packages which can be flown on small, less expensive satellites. The addition of hyperspectral capabilities does not add weight or volume as rapidly as does image resolution, and a hyperspectral sensor with a spatial resolution of 10 m probably optimizes cost and coverage. Systems can be inexpensive enough that advances in processor and sensor technologies can be incorporated in a timely way. Technologies are improving significantly on a timescale of two years—a time consistent with commercial satellite system development times. *A two year period from the beginning of design to launch should be a firm goal. Opportunities for leveraging commercial technologies are many in this area.*

The ultimate utility of a distributed satellite system, a distributed URAV system or a distributed information system of any type derives from cooperative action. Multiple systems which improve performance linearly with the number of objects deployed are not properly classified as distributed systems. True distributed systems increase performance at a rate which is faster than linear with the number of systems deployed. In some cases, for example, a single satellite can perform processing tasks for a large number of special purpose satellites if an onboard communication link is smaller or lighter than a dedicated processor. A central processor will reduce the processing requirements of individual satellites in the constellation. Processors usually are sized for peak rather than average loads, and a central processor can be operated more efficiently than a large number of small ones. In addition to central processing, cooperative detection is possible. For example, several satellites, each of which has a view of a particular

region of interest could measure the phase of a transmitter simultaneously to determine the phase of an emitter. The long baseline will make precise location of the emitter possible.[36] We have discussed the use of commercial imaging for mapping[37] and the use of commercial constellations for providing communication services for onboard military hyperspectral systems.[38] Those discussions will not be repeated here. Rather, we will concentrate on access to space, control of space, and the projection of power from and to space.



Distributed Satellites Cooperatively Scanning a Target Area

6.2 Access to Space

The use of space has been limited by the high cost of placing satellites in orbit. The cost of mass on orbit is approximately $20,000 per kilogram. Many studies of space launch have searched for ways of reducing cost, but none have proposed a definite way of reducing cost substantially. We have no specific solutions, but we will suggest long term research which may help.

The computational design of molecules is becoming possible as the result of increasing computation power. *The Air Force should substantially support research into the*

36. Sec. 2.1 of this chapter
37. Sec. 2.0 of this chapter
38. Sec. 2.5 of this chapter

computational design of energetic materials.[39] Both explosives and rocket fuels should be included. It may be possible to develop fuels which have higher specific impulse, Isp, than those available now, but the use of these materials is not a simple matter. Higher Isp is related to higher exhaust velocity which, in turn, is related to higher combustion temperatures. Thus, an increase in Isp can require combustion chamber materials which will operate at temperatures and pressures higher than do those currently available. We should, therefore, search for Isp increases which are not achieved by increasing combustion temperature.

Of course, lighter satellites can reduce the cost of launch for a particular function even though the cost per pound is not reduced. Mass reduction can be achieved through the use of lower density, stronger materials and through the use of stronger lightweight structures. In the longterm biological structures may be useful.[40]

Reusable launch vehicles have been proposed as a way of reducing launch cost. It appears, though, that the cost of vehicle preparation dominates the cost of vehicles. Launches are prepared and monitored by a "cast of thousands" operating a vast array of equipment. Reusable vehicles amortize their cost over a large number of launches, but unless they have greatly reduced logistics tails, little reduction of cost can be expected. If a reusable vehicle is to be cost effective, it must need little refurbishing and testing between launches. The goal should be to achieve "airplane-like" operation of space launch vehicles. Today, space launch is more akin to a science experiment than to a routine takeoff. This situation must be changed if cost reductions are to be achieved. Utilization of the rapid increase in capability of information systems should reduce the number of people required to launch a space vehicle.

Automated launch control and mission monitoring systems should be designed to reduce the number of people involved in launch and mission control by at least a factor of ten.

Orbit transfer from low earth orbit to geosynchronous orbit can be addressed by electric propulsion. Research in this area should be strengthened.

Although military launch capability must be maintained as a vital part of national security readiness, *our goal should be to launch most military satellites aboard commercial launch vehicles.* The use of commercial capability will necessitate the design of military satellites which are compatible with the available launchers. The distributed constellations do just that. The norm should be satellites of volume and mass similar to those of Iridium or Teledesic. It will require discipline to produce satellites that have only one function, but cost, functionality, and reliability will demand single, or perhaps dual function satellites. Reliability is now a problem with commercial launch vehicles, but this situation will improve. We should be prepared for launch failure probabilities of 10-15 percent in the initial years of deployment of constellations. Reduced reliability dictates lower cost satellites, and smaller, distributed systems are, again, favored. Miniaturization, reduced design and planning time, and single or, at most, dual purpose satellites will make space systems affordable.

39. Space Technology Volume
40. Materials Volume

6.3 Space Control

Control of space will become essential during the next decade. We will depend on satellites to provide Global Awareness and Dynamic Control for our Forces, and *commercial services may be a threat to those Forces.* As commercial involvement of US companies in space increases, *the United States may be called upon to protect nonmilitary space assets from attack by terrorists or a rogue nation.* We should be prepared to execute three missions:[41]

- Protect US military space assets and launch capabilities.
- Deny the use of threat assets.
- Protect allied, non military space assets.

Various antisatellite (ASAT) weapons that direct projectiles or fragments against threat satellites have been developed or proposed. Kinetic energy systems such as these are expensive. The vehicles are complex, and tracking and guidance must be precise. Most of the cost, however, is the result of maintaining readiness to launch within an acceptable time, such as 24-48 hours. There appears to be no way to reduce the cost of readiness in the near future. In the main, space based communication systems are not invulnerable to jamming. The task of directing a laser at a satellite is not an easy one. Laser power of a megawatt or more will be needed, and precision tracking and pointing systems must be developed. We believe, however, that it is possible to develop such a system in less than a decade. *Therefore, we recommend ground-based Directed Energy weapons to attack threats in space.*

It is less obvious that high power microwave (HPM) systems may have a role in space control, such microwave systems could be attractive because they have the potential to produce electronic upset without damaging the structure of a threat satellite. Thus, HPM systems may be more effective at producing temporary denial of capability than a laser. Phasing technology used in radio astronomy could be applicable to the problem. *We should consider the possibility of a very large array of independently phased dipoles spread over a kilometer diameter.* The diodes could be phased to form a sparse synthetic aperture for projecting microwave power into space.

Protection of military satellites might be enhanced to some extent should the application of stealth techniques be possible, but if distributed systems become the norm, the redundancy of systems will provide protection. Solar panel area is large, and panel position cannot always be set to minimize observability. *Even if possible, we do not believe that the increased cost of low observable satellites will be justifiable.*

Because of cost, it is unlikely that many countries will develop ASAT weapons. It is well known that GPS is vulnerable to jamming because of the low power in the navigation message.[42] Power of a few watts can jam the Clear Access (C/A) code at a distance of 10-20 km. Nulling antennas can provide increased jam resistance, but the only long term solution is to increase the signal-to-noise ratio as described above.[43] Protection of other systems can be

41. Space Applications Volume
42. *Journal of Navigation*; Spring 1993, and SAB Report - *GPS Survivability and Denial*, November 1993
43. Sec. 2.6 of this chapter

enabled by munitions directed by coordinates to the jammer. Current practice is to launch missiles which home on the signal whether it be a jammer or a communication or radar source. Accuracy and kill probability could be improved dramatically by the distributed satellite signal detectors described in Sec. 2.1 coupled to GPS munition guidance. It is possible to field a system whereby cooperative satellites could provide signal coordinates quickly to an accuracy of a few meters, and GPS guided munitions can strike to a comparable accuracy even if the source emits only for seconds, or less. Overall accuracy should be 5-10 meters. It should be possible to build coordinate-targeted missiles having range of 100 km at a cost of $100-150K. This system will provide robust protection against the most common threat to US and allied space assets.

6.4 Force Projection from Space

There are political issues related to the projection of power from space, but we treat only the technological ones. Two classes of weapon have applications from space—directed energy and kinetic energy. Of the two, only the directed energy weapon offers attractive features such as reusability, speed-of-light response, and training and testing features. Kinetic energy weapons having the same energy as orbital weapons can be delivered by ICBM from the CONUS. Response time can be nearly that of an orbiting weapon, and the cost of readiness is lower. *We recommend that the ICBM option with terminal, coordinate guidance be used if delivery of kinetic energy weapons from space becomes an operational requirement.* Of course, the issue of distinguishing nuclear weapons from conventional weapons must be addressed. Therefore, we will discuss space deployment of directed energy weapons.

Because of the large distances from space to target high power radio frequency (HPRF) weapons will require antennas having diameters of 5-10 km and powers of at least kilowatts. If development of extremely lightweight structures and wavefront compensation methods in the microwave frequency range succeed, such weapons will be possible. We believe, though, that the short wavelength and high power of lasers will favor the space deployment of high power lasers rather than HPRF.

Two deployment options are available. First, a laser device can be deployed in space along with beam directing optics and control systems. Space deployment of lasers will involve significant problems in logistics, resupply, and training in addition to those of targeting and control. Consumables in the laser system will result in very high system costs. The minimization of these costs will demand electrical lasers and compact energy storage systems. Phase locked solid state diode lasers are the preferable device because they achieve electrical efficiency of 50 percent and they have excellent beam quality. Large optical elements with wavefront compensation will be essential for long-range capability.

The second option is to construct the laser system on the ground and to deploy targeting mirrors in space. Again, large structures and wavefront compensation to compensate for optical imperfections will be necessary. But, many logistics problems associated with space basing will be eliminated, and more choices of laser will be available. Laser power will not be limited by satellite power or by available fuel. The system satisfies that most basic of principles that one should always minimize the complexity of the space component. The idea of directing ground

based lasers with space based mirrors is not new. The new technologies which can be applied to the problem, though, are those of lightweight structures[44] and nonlinear optics.[45] Control technologies will also improve during the next decade. We believe that if projection of directed energy from space becomes a reality it will be in the form of ground based lasers and space based relay mirrors.

7.0 People

New World Vistas looks decades into the future. We predict increasing dependence on autonomous weapons and information systems. During the entire period, we see people as central to Air Force operations. *Therefore, the design of systems must include the "human system" as an integral part.* Increased tempo of operations and reduced Force size will demand that people interact with weapons systems more efficiently than ever before. Science and technology can assist the process of human interaction with the machine of the future. Improved and specialized training can assist the process of interacting with the machine of the present.

7.1 Modeling the Human

We are accustomed to modeling the performance of weapon systems and interactions among systems. We model groups of humans such as Army units in engagement and maneuver models. We do not, however, model the individual behavioral characteristics of humans. Significant improvements in simulations of engagements could be made by including human qualities such as leadership, cohesion, experience, intelligence, and level of training. It has been noted by General Fogleman that simulations have been unable to explain what modelers assessed to be the apparently irrational behavior of the Iraqi Republican Guard during Desert Storm.[46] He correctly notes that continuous bombing by B-52's is likely to provoke strange behavior in anyone. The goal of human psychological modeling should be to include individual behavior in the design of systems and in engagement models.

Detailed physical models of humans will be valuable in the design of weapon systems. Improved modeling of human structure, motion, and performance will provide valuable input to the design of new weapons. These models should describe the response of humans to weapons as well as the interaction of the human with the system.

7.2 Training

Training is one of the largest consumers of Air Force funds. Training efficiency can be greatly improved by making it more individual.[47] The tailoring of training to the individual had its embryonic beginnings in the computer and video training systems which are now common. We believe that it is necessary to further develop technologies related to:

- Personnel selection and classification systems

44. Space Technology Volume and Materials Volume
45. Directed Energy Volume
46. General Ronald R. Fogleman; Speech - NATO Brunson, Belgium, NATO Air & Ground Component Commander Conference, September 95
47. Human Systems/Biotechnology Volume

- Cognitive and non-cognitive models of the learner and the instructional process
- Computer technology to support training simulations, training equipment, and training management systems

Improved training can be affected through distributed interactive simulations. Simulations which use humans as foils in training will be more realistic than those which use scripted or probabilistic computer responses. Commercial organizations have begun to use interactive simulations in futuristic video games.[48] Participants note realism far superior to that of other video games. It is possible that displays and methods developed by the entertainment industry can be applied to Air Force training problems.

7.2.1 Flight Simulation

Flight simulation is a special case of training which is of special interest to the Air Force. The utility of simulators in commercial airline operations has been demonstrated to be profoundly effective in increasing pilot performance while reducing aircraft training hours. The Air Force must acknowledge that the aircraft it now owns will be the largest part of the fleet in the early years of the 21st century. It is essential that those aircraft be capable until they are replaced by newer ones.

Simulators for transport aircraft use well known technology and training procedures, and equipping the Air Force with simulators which could eliminate almost all training in aircraft is a straightforward process. The initial capital cost will be high, but the life cycle cost of transports will be far less than if aircraft are used for training. There should, however, be continued research into the minimum requirements for meaningful simulation of Air Force flight conditions. For example, can a substantial fraction of flight training be done in simulators without motion? A considerable body of work exists in this area, and the Air Force should integrate it into planning of the simulator "fleet."

Simulators for high performance aircraft are another matter. Only the Air Force, Navy, and Marine Corps can develop the necessary technology and the necessary training and testing programs. It may be that the sense of "being there"[49] requires the simulation of sensations which are not required for a transport aircraft. However, total fidelity of "being there" in simulation is very expensive and may not be necessary. *The relationship of artificial sensation*[50] *to training effectiveness should be investigated carefully.* For example, it is possible to build a simulator which will produce appropriate g-forces on the pilot. The forces would be produced by a rotating device with smaller radii of curvature than experienced in a fighter aircraft, but the sensation could be made quite accurate. It is likely that joint programs in this area could be very productive.

7.3 Education

Training and education differ in that education is less specific and more encompassing than training. Training produces the capability to perform a limited number of specified jobs

48. Sec. 7.4.1 of this chapter
49. Sec 7.4 of this chapter
50. Information Technology Volume

with high efficiency while education prepares a person to respond effectively to unanticipated situations. The Air Force of the 21st century will be far more complex and technical than the current Force. That situation will be partly the result of the use of higher technology in weapon systems, but it will result mostly from the integration of systems as we have described. Air Force people of the next century must be problem solvers in a milieu which is constantly changing. The only known approach to such issues is through education.

Internal technical capabilities in the Air Force Laboratories will decline as the result of political and budget forces. The people who purchase weapon systems must be "smart buyers," but it is unlikely that they can achieve "smart buyer" capability unless they are educated in a technical field and have some experience working in that field.

We suggest that the Air Force increase the number of technical degrees at the Masters level substantially through funding of degrees at both AFIT and at Universities. PhD. degrees should be increased as well, but a careful study should be done to determine appropriate staffing levels. Quality of a degree should be a factor rather than simply its existence. Rating system for Universities and Colleges exist. AFIT should participate to the extent that its curriculum overlaps that of civilian schools. *Degree quality should be a factor in civilian and military promotion.*

Practical experience beyond degree should be a part of technical education. As Defense Laboratories accommodate fewer people, experience can be gained by assignments to industry and National Laboratories. Buyers with lab or industry experience will be far "smarter" than those without.

7.4 Human-Machine Interaction

The Air Force will depend increasingly on computer-driven operations at high tempo. Errors and delays associated with the interaction of human and machine can cost lives. The human is fundamentally an analog device, and the computer is a digital device. We communicate with computers through the keyboard and the mouse or through modifications of those devices. Neither permits much creativity. Both operate at bandwidths below that of the brain-eye-hand combination. Rapid unanticipated trained response such as that of a fighter pilot in combat is not possible, in general, with current computer input systems. Flight simulators are, of course, exceptions.

Technology can increase the speed of interaction by reducing the inertia of mouse and keyboard. For example, one can use eye motion to direct a computer cursor rather than a mouse or roller ball. Marginal speed increases can result, but the fundamental nature of the interaction does not change. Speech interpretation technology is developing, but it, too, will not lead to a substantial increase in the speed of interaction. Speech, after all, is highly redundant. The rate of information flow in speech is much slower than the rate of human motor response, such as, pushing a control button.

We admit to having no specific suggestions for increasing the bandwidth of human-machine interactions. *We do, however, recommend that research in methods which have the potential for changing the inherent qualities of that interaction while increasing the speed of interaction*

be aggressively pursued. The ultimate interaction is thought control.[51] The direct coupling of brain and machine is beginning now with applications in injured and diseased victims. The Air Force should aggressively encourage and exploit this emerging technology.[52]

7.4.1 Commercial Technology

Entertainment companies are developing at breakneck speeds new ways for humans to interact with machines . The intensity of the battle among companies is indicated by their being among the most profitable corporations in the world. While companies do not publish their investments in technology development, it is probable that these investments dwarf that of the Department of Defense (DoD). It is certainly true that the best students in computer and information science are vying for positions in entertainment companies.

It may be that no specific products of the entertainment industry will be of use to the Air Force. However, the thrust of entertainment technology is to convey a sense of "being there" to an audience or to a group of participants. Successful development of such a technology would qualify it as revolutionary. The impact on teleconferencing, collaboration at a distance, flight simulation, UCAV operation, and many other applications would be enormous. *We urge the Air Force to establish continuing contact as closely as possible with entertainment organizations.*

7.5 Chemical Intervention

It is a fact that human operational performance can be enhanced or extended in time by chemical means. The issue is to what extent enhancements can be achieved without side effects. Air Force people will be called upon to travel large distances and to operate at peak performance immediately for extended periods. *Research on means, chemical and other, to reduce the physical and psychological effects of large changes in longitude ("jet lag") should be continued.* In life-threatening situations it will sometimes be necessary to extend the time over which a person can function at an acceptable level without rest. *Although we believe that such extension of performance can never be completely free of side effects, the search for effective drugs which minimize these effects should be continued.*[53]

8.0 Primary Technologies

At this point the reader has probably concluded that the technological Air Force of the 21st century may be effective, but that it will certainly be incredibly complicated and unaffordable. If the capabilities described earlier were developed as the sum of many systems, both statements would be true. In fact, if the overall capability of the Force were merely the sum of capabilities of individual systems, a modern Air Force would be unaffordable. We have emphasized that the strength of *New World Vistas* technologies lies in their integration. To demonstrate this assertion we will identify the individual technologies necessary for achieving the result we propose. A detailed list and recommended actions will be given in Chapter III. Technologies marked with a (R) will generate revolutionary capabilities. Technologies marked with an asterisk (*) will be pursued in both commercial and military forms. It is currently not clear whether the Air Force decision should be to develop or to buy. They are duplicated on the list.

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51. Information Technology Volume
52. & 53. Human Systems/Biotechnology Volume

Technologies to be developed:

- (R)UCAV structures and engines - including hypersonic operation
- Remote control technologies
- Composite, tailored materials for air and space
- (R)Large lightweight structures for optics and antennas
- Nonlinear optic compensation
- (R)High power, short wavelength lasers with emphasis on phased arrays
- (R)High power radio frequency sources
- (R)Active and IR stealth
- (R)Point of use delivery starting with low cost precision airdrop
- Next generation airlifter - higher wing and engine efficiencies
- (R)Automated, reusable space launch vehicles with "airplane-like" operations
- High Isp engines for low earth orbit flight
- High bandwidth laser communication for satellite and aircraft cross- and down-link*
- (R)Distributed satellite vehicles and sensors
- Precision station keeping and signal processing for distributed satellite constellations
- Radiation resistant satellites
- Precise positioning overlaid on military and commercial information
- (R)High precision, jam resistant GPS
- Hyperspectral sensing and target identification at low spatial resolution
- (R)Human-Machine interactions*
- (R)Information munitions
- Information protection
- Chemical enhancement of biological functions
- Continuous simulation
- Secure operations across large networks having secure RF components*
- Language translation of stylized language
- Micro-electro-mechanical systems for sensing and manipulating*
- Nuclear hardened electronics

Technologies to buy:

- Software tools and languages
- High bandwidth laser communication for satellite and aircraft cross- and down-link*
- (R)Human-Machine interactions*
- Information protection*
- Operations with large databases*
- Secure operations across large networks having secure RF components*
- Micro-electro-mechanical systems for sensing and manipulating*

Services and equipment to buy without development:

- Mapping of the world to 1 m[53]
- High speed processors
- Space launch
- Satellites
- Focal Plane Arrays
- Database software
- Data compression systems
- Computer displays
- Networking technologies
- Direct downlink broadcast equipment
- Satellite to aircraft communication equipment
- Fiber and satellite communication services
- Training systems

There are, of course, support technologies which accompany the major ones. We believe that the reader will agree that the list is manageable if not short. Much of the work listed is in progress today either in DoD or commercial laboratories. Most of the components of information systems can be purchased today.

9.0 Conclusion

We have described the technologies which will make the United States Air Force the most capable and respected Air and Space Force in the world of the 21st century. All of the capabilities enabled have connections to the other Services, and provisions are made for allied

53. Wall Street Journal, November 30, 1995, pp1

operations across networks, databases, and languages. Response times enabled by these technologies and concepts will be measured in seconds for mission generation or, even in microseconds for information responses. The technologies described are at the edge of the currently possible, or, even beyond the edge for a few years. Some of them may not materialize as warfighting capabilities. Forecasting is not an exact science, and the path will wind as it disappears into the shadow of the future. We guarantee the journey to be productive even if the road ends at an unexpected place.

It is incumbent upon the members of the SAB, Air Force technologists, and warfighters to discuss and refine the concepts presented here. The capabilities described are natural ones for scientists and technologists, but we must transform the technical-operational concepts into forms more useful to the operational Air Force. Then, we must transform the concepts into technology programs. Finally, we must transform the programs back into capabilities. When the product of the three transformations is unitary, that is, the result is the same as the starting point, we will have reached a true understanding among all participants.

Chapter III

Recommended Actions for the Air Force

What to Do and What to Stop Doing

Resources to Get There and How to Make It Happen

1.0 Introduction

Up to this point, this Summary Volume has presented a list of essential capabilities for the Air Force of the 21st century and provided rationale as to why. The purpose of this Chapter is to propose to the Air Force a top level summary of what technology groups should be developed to produce Air Force future capabilities necessary for it to continue into the 21st century as the world's best and most respected. As described in Chapter II, these six capabilities are outlined as follows:

- Global Awareness
- Dynamic Planning and Execution Control
- Global Mobility in War and Peace
- Projection of Lethal and Sublethal Power
- Space Operations
- People

In the interest of brevity, our intent is to suggest the major "leap ahead" technology areas that need to be pursued. We have referenced the Panel Volumes by footnotes, and the readers are asked to consult the appropriate Panel Volume for details. Those volumes are the major works of *New World Vistas.* They contain the details needed to build and execute specific research programs. After recommendations on what to do in each of the capabilities mentioned above, recommendations, where appropriate, on what to stop doing or not to do will be provided to help focus time and resources. And finally, after the discussions on what to do and if needed, what not to do, will come a funding proposal to get the effort started in the right direction and a suggestion concerning how to track matters to see that the undertaking remains *on course and on glide path.* We shall begin with consideration of the six generic capabilities mentioned above.

2.0 What the Air Force Should Do

2.1 Global Awareness

A future goal of the Air Force should be to know at all times the relevant global military situation given the existing political and economic conditions and the state of military conflict. Such awareness should be in near real time (in time enough to understand and act) and with near real perfect knowledge (knowledge good enough to make good decisions in the time available to decide and act). This is the idea of Global Awareness. Some will argue, and we do not disagree, that this is or is not a part of Information Warfare. In this regard, we recognize the importance of Information Warfare in the future and that much of what we present in this summary volume is Information Warfare said another way. The key technologies to make Global Awareness possible lie in the right mix and integration of sensors, communications, and processing to collect data and convert it into information and knowledge in a meaningful time frame over the area of interest. The reader is invited to study closely the Information Technology, Information Applications, Sensors, Space Applications, and Space Technology volumes of this study for details. A top level list of the relevant technologies are outlined without comment as follows:

- Clusters of cooperating satellites
  - Precision station keeping
  - Autonomous satellite operations
  - Signal processing for sparse apertures
  - Laser cross and down links
- Precise global positioning, time transfer, and mapping[1]
- Large, sensitive focal plane arrays and associated read out
- Radiation resistant satellites and components
- Spectral sensing at all relevant wavelengths
- Active sensors
  - Large light weight antennas
  - High efficiency radio frequency sources
  - High energy lasers
- Micro-electro-mechanical systems[2]
- Communications and networking
- Automated fusion[3]
- Automated target recognition[4]

2.2 Dynamic Planning and Execution Control

The first step toward acquisition of Dynamic Planning and Execution Control capability is to *make this idea or concept part of Air Force and Joint Doctrine*. Next is to *pursue a joint architecture* definition to implement the doctrine. The concept of Dynamic Planning and Execution Control is to exploit the Global Awareness acquired through the technologies just listed above. As such, this idea will make possible the most efficient use of the mobility, power projection, space operations and people associated with the military capabilities of the United States. The attainment of relevant Global Awareness and its exploitation through Dynamic Planning and Execution Control will be a high leverage capability to win America's future wars quickly, decisively, with minimum or no human losses (on both sides). As with Global Awareness and the capabilities in this chapter, this topic is replete with information warfare aspects and can be viewed in that context as well as in the functional categories used for this presentation. The following technologies summary applies to support Dynamic Planning and Execution Control:

1. Space Applications Volume
2. Sensors Volume
3. Information Applications Volume
4. Sensors Volume

- Support for Planning. Faster than real time interactive, predictive, continuous running simulations for planning and mission rehearsal will the driving technology for planning side for future employment of air and space power.
- Support to mission execution. Execution of the plan is where the true flexibility and speed of employment of air and space power will be realized. Technologies which permit near real time changes and updates to on-board databases as well as other planning and situational awareness databases will be key. Rapid capture of information from on-board sensors, including the crew, into these databases will also be very important. Finally, concurrent faster than real time simulations for near real time mission execution, planning, and attack will insure we remain inside any enemy's timeline for action.

2.3 Global Mobility in War and Peace

The United States military has a long tradition of going where necessary in the world to conduct military and peaceful operations. Such a capability will perhaps be even more important in the 21st century. The Air Force brings speed and reach to the global mobility equation. The current introduction of the C-17 will serve the country well as we enter the next millennium. The following technology areas are recommended to make a difference in the use of the C-17 and after the C-17.

- *Point of Use Delivery*. The idea here is that supplies delivered by aerial transport should be delivered directly to where they are to be used without landing the transport aircraft. Delivery of medical supplies beside the hospitals, food directly to the soldier or feeding facility, and weapon system load and reload ammunition to the weapon in its firing position are possible examples. Secure dependable communications, precision airdrop, multi- spectral sensors for weather and intelligence, intransit visibility of cargo, aircraft situational awareness and aircraft self protection are the key technologies.
- *Low Cost Precision Airdrop*. A key driver in making "point of use delivery" possible will be the need for a low cost way to dispense air cargo in modules, containers, or pallets with appropriate guidance, control and arresting mechanisms. A proper balance of expendable and reusable components is needed to achieve the results within a reasonable cost.
- *The "Million Pound" Airlifter*. Thinking needs to begin now for the next generation airlifter. High lift over drag wing/airframe design and testing needs to begin. Engineered materials[5], high temperature engine components, composite fabrication and fastening, and next generation material for airframe and skin are needed.

2.4 Projection of Lethal and Sublethal Power

The four major technology directions that the Air Force should pursue to project lethal and sublethal power in the 21st century are outlined as follows. There is a fifth technology having to do with Space, but it will be covered later in the Space Operations section of this chapter.

5. Mobility Volume

- *Uninhabited Combat Aerial Vehicles (UCAV).* As this technology is developed it will offer potential for significantly more capable weapon systems at lower cost. Such vehicles serendipitously accommodate the probably inexorable trend of American society which are more and more expecting no human losses during U. S. military operations. The technologies to realize the UCAV include new high efficiency, high supersonic engines; advanced structures; avionics, control systems, and observables; very high altitude/low speed cruise, very small/miniaturized "micro-air vehicles"; very high dynamic pressure cruise vehicles; intelligent signal and data processing; secure and possibly redundant control data links; control science and applications for mission and vehicle management of a complex, highly coupled system, control criteria to achieve optimal performance based on that used for missile control; and human/machine interface for off board air vehicle control.
- *High Power Microwave and High Power Laser Directed Energy Weapons.* Speed of light weapons with the full spectrum capability to deny, disrupt, degrade and/or destroy will leap past and could eventually replace many traditional explosive driven weapons and self protection countermeasure systems. There are five innovative technologies required for "energy frugal" practical directed energy weapons.[6,7] They are large, lightweight optics, HPM antennas using thin membrane fabrication; high-power short-wavelength solid-state lasers; high average-power phase conjugation; new approaches to adaptive optics and phased arrays of diode lasers.
- *Stealth-the Next Plateau.* Active radio frequency and next generation passive infrared stealth capability will replace what we have today with another quantum leap forward in vehicle survivability.
- *Hypersonic Air Breathing Platforms/Vehicles.* Even with the tremendous increase in space operations in the future there will continue to be a major place for air breathing platforms/vehicles. Time is now, always has been, and even more so in the information age future, will be of the essence in military operations especially those of the Air Force. All distances on the earth are fixed. If the Air Force is to execute faster than an enemy in the 21st century, then to reduce time, the only alternative is to go faster. Hypersonic air breathing flight is as natural as supersonic flight. Advanced cycle, dual mode ramjet/scramjet engines and high temperature, lighter weight materials which allow for long range, long endurance, high altitude supercruise are the enabling technologies.[8]

2.5 Space Operations

Space operations will grow rapidly as a factor in United States military capabilities limited primarily by affordable access. Space operations already contribute much to global observation and global situational awareness. Space control and projection of force from space technologies will become as important in the 21st century as space becomes more available to many countries of the world.

6. Directed Energy Volume
7. Space Technology Volume
8. Aircraft and Propulsion Volume

- *Access to Space.* Affordable access to space will require many advances in technology. Such technology includes lower mass of the components for power, energy storage and conversion, attitude control, propulsion, large-thrust, high-specific impulse chemical propulsion, multi-functional structures that integrate spacecraft bus functions into the structure of the spacecraft itself, high temperature materials, ultra-light-weight integrated cryogenic structures and miniaturized sensors.
- *Global Observation and Situational Awareness.* Sensors, the conversion of sensor data to information and knowledge, the necessary communications to move the data, information and knowledge when and where needed are necessary for global observation and situational awareness. Although such activity may be conducted in both the air and space medium, the use of space will continue to grow and begin to dominate in the 21st century. The technical trades and costs associated with global observation and situational awareness from either air or space will have to be made as the decisions to replace or improve current capabilities are faced. In the mean time, there are many technologies needed regardless of whether the job is done from air or space. These technologies are outlined in the previous section on Global Awareness.
- *Space Control Technologies.* The Air Force must begin to think and bring forward the technologies necessary for space control. Capabilities to defend our own space based resources and to disrupt, degrade, deny or destroy that of the enemy will be needed sooner or later in the 21st century. The technologies needed to protect our space resources from enemies include high thrust, high specific impulse electric propulsion, large constellations of low cost satellites with distributed functionality or networking across the system and autonomous guidance & navigation.
- *Force Projection from Space.* The laser directed energy weapon mentioned above in the "Projection of Lethal and Sub-lethal Power" section may be employed from space. Alternatively, the laser can be ground based with directing mirrors deployed in space. Short wavelength, electric lasers along with large optics and antenna technology will be needed. In addition, for space deployment of the laser, large electrical prime power such as nuclear or power beaming along with power storage in advanced capacitors or secondary advanced flywheels will need to be pursued. The sensor, communications and autonomous guidance and navigation technology needs mentioned above will contribute to force projection from space.

2.6 People

There can be no question as we enter the 21st century that the idea of the individual's central importance will continue to be a driving force in our culture. As such, the expectation of the American people (perhaps unrealistic but nonetheless powerful) is that there should be almost no casualties during the conduct of military operations. In addition to the capabilities and technologies mentioned above, attention must be paid to the technologies which will improve the human part of the military capability equation. Those entrusted with the defense of our country must be well trained, able to control and work with machines and information systems in the most efficient way and be mentally and physically superior within moral and ethical

bounds to any enemy. The five human-related technology areas that will allow significant improvements in human performance are summarized as follows.[9]

- *Training.* Training can be significantly improved and made less expensive through personnel selection and classification technologies which more closely match skills and aptitudes to the task. In addition, interactive individual and group training using virtual reality and other distributed interactive simulation where appropriate will be the training technologies of the 21st century.
- *Human/Machine System Fusion.* Voice recognition and voice generation, gesture recognition and response, multi-lingual translation and generation and brain control of computer technologies will all contribute to making sure that the human is not the limiting factor in rapid exploitation of Global Awareness through Dynamic Planning and Execution Control.
- *Operational.* In order to better understand, design and operate the weapon systems of the next century a more detailed understanding of the human is needed. Technologies associated with cognitive and non-cognitive models of the human learner and of the instructional process are needed. Such understanding not only will help with the training needs listed above, but will make possible the most cost effective human machine fusion in such areas as displays and controls, brain control of computers, etc.
- *Biological.* Technologies which temporarily enhance human performance and provide for emergency mission extension should be developed. The technologies should be brought forward into capabilities under the social and ethical standards of our country and leave no short or long term after effects. It is expected these capabilities will only be used on the most difficult and dangerous missions. We owe with proper controls, such capability to our people who must do the military job just as much as we do the best tank, ship or aircraft if we truly believe that wars are best fought to win quickly, decisively and with no or minimum human losses.
- *Scientific and Technical Personnel Management.* Air Force leadership from the days of General Hap Arnold to the current Chief and the Secretary recognize that science and technology is the life force of our country's air and space capability. We must have a path for more scientific and technical officers to attain the highest positions in our Air Force. We, therefore, recommend that the Air Force officers who command laboratories be given the status and be treated in the promotion system like other operational wing commanders. Please refer to Chapter IV on "Organizational Considerations" for more on the management of Air Force scientific and technical personnel.

9. Human Systems/Biotechnology Volume

3.0 What the Air Force Should Not Do or Stop Doing

Much work and study has gone into how the Air Force can leverage its science and technology resources with the technologies the commercial world will bring forward to the Air Force in the coming years. There are also technologies or development initiatives internal to the Air Force which have little chance of being converted to actual capabilities. With this in mind, the following is a representative summary list (which is probably incomplete) of technologies the Air Force should stop doing all together or at least by itself.

- Stop Buying Bandwidth to the Theater
- Stop Software Development of Software Tools
- Stop Development of Compilers
- Stop Mandatory Use of Ada
- Stop Selective Availability of GPS
- Stop Environmental Protection Research in Air Force Labs
- Stop Aircraft Cockpit Design Work - Depend on aircraft manufacturers
- Stop Ejection Seat research and development - Depend on aircraft manufacturers
- Rethink MILSTAR
- Stop Military Only Launch Access to Space - Exploit commercial systems
- Rethink the design of and investment in dedicated Military Satellite Communication Systems[10]

Defocus Air Force investments to utilize commercial and university developments in the following areas:

- High capacity communications "backbones"; global telephone networks; world-wide wireless infrastructure, Internet, ATM
- Cryptography routinely embedded in systems
- Compression (except intelligent compression)

In some areas, the Air Force laboratories should recast themselves as *users* of commercial and university research, rather than basic developers. These areas include:

- Multimedia technologies
- Natural Language Understanding, including Speech Understanding
- Computer displays
- Data mediators, request facilitators, information broker software

10. Chapter II, Sec. 3.3

- Basic directed-action software agents
- Software for the "business" functions of the AF: logistics, personnel, finance, etc.

For example, the Air Force may make heavy use of commercial smart agents within its command and control systems. However, the core research in these areas is best left to the university and commercial communities.

As with many things in life, the decision on what to stop doing is not simple. Complicating factors include a sincere entrenched bureaucracy which will resist.

We recommend that the Air Force establish an independent, outside panel to review priorities of S&T programs. A concentrated effort should be made to eliminate 5% of S&T programs each year. Funds for the discontinued programs can be applied to new programs.

4.0 Resources to Get There

We recommend that the Air Force invest 15% of its S&T resources over the next five years in new start S&T areas directly related to *New World Vistas* proposed technologies. Such an investment policy will do two things. First it will cause the Air Force to invest in long term key technologies which are not under the current mandate of immediate short term pay off. Such activity will make possible the longer term view needed to create the quantum leaps in capability in the next century. Second, such a policy will act as a forcing function on what to stop or curtail to find the resources for the longer term investments.

5.0 How to Make "*New World Vistas*" Happen

We recommend the SAB sponsor and coordinate workshops, briefings, SAB member participation on panels and forums, and other appropriate activities to extensively communicate the essence and details of New World Vistas.

We recommend the Principal Deputy Assistant Secretary of the Air Force (Acquisition) (SAF/AQ) be responsible for leading the effort within the Air Force to determine what and how *New World Vistas* is to be implemented and how progress will be measured and tracked.

Chapter IV

Organizational Considerations and Recommendations

1.0 Introduction

New World Vistas describes a new way of combining and integrating Air Force technologies and capabilities. It is natural to assume that the structure and philosophy of the organization must make some concessions. The operational capabilities enabled by the new technologies are closely paralleled by today's capabilities. While the ratio of forces in various commands may change and the equipment and individual tasks may change, the generic functions will be quite similar. It is in the technology and procurement organizations that fundamental change will manifest itself. There should be changes made in personnel practices as well. We will recommend changes that we believe to be constructive and positive. Finally, we will recommend some functional changes within SAB operations.

2.0 Procurement and System Development

Everyone rails at the procurement system as the source of all unjustified expense and interminable delays. We will not repeat the well known arguments. We will only suggest that completion dates have the same status as other specifications of a system. Many of the systems suggested by *New World Vistas* can be built a piece at a time, and funding reductions should be reflected in the extent of the system rather than by extending the procurement time. The systems need to mesh with one another, and, therefore the relative phasing of procurements is important. These considerations suggest that systems be procured in blocks which continuously replace older blocks and continuously insert new technology in later blocks. One can argue that this has been the philosophy of many procurements, and we have chosen the nomenclature to suggest this argument. While this is true to some extent, the procurement cycle time for many of the concepts in *New World Vistas* should be no more than two years, and replacement time for information systems should be no more than 5 years. The system should be redesigned to accommodate these times. It is known in the commercial world that extended development periods lead to excessive costs. The Defense procurement system stretches programs in time so that many programs can be pursued in parallel. Both Government and Contractor have become too comfortable with this situation. We should consider the possibility that programs in series with rapid completion may be more economical.

The existing organization is optimized for the development and procurement of independent systems. It was emphasized many times that the effectiveness and affordability of capabilities depends on their close integration. The ideal situation would be one in which all participants in all procurement and development projects interacted at all times to produce systems which naturally worked together in the most efficient way. The ideal situation is impossible. Even if people could be convinced to behave in the proper way, they would spend so much time cooperating that they could get no work done. While we must instill the importance of the concepts of integration and cooperation of systems in all Air Force people, government and contractor, we must realize that focus on an individual product is the natural tendency of techno-humans.

Therefore, integration and interoperability must be assured at a higher level than that of individual system development and procurement. We recommend that an Integration Authority be established to guarantee integration and interoperability. We use the terms assured and guaranteed rather than dictate to indicate that the function of the Integration Authority is not to hand down specifications. That has been tried before, and it tends to stifle innovation and to stagnate

technology. The specification of Ada is an example. Rather, we envision an Integration Integrated Product Team (IIPT) approach under the command of the Integration Authority. The IIPT would be composed of knowledgeable members of all interacting development projects. They would be responsible for proposing program and system modifications to facilitate integration and interoperability. The teams could also specify common components which could be separated from several projects into a common procurement to reduce cost. The purpose of the IIPT's would be to produce global optimization of systems rather than the sum of local optimizations that we have today.

We believe that the Integration Authority and IIPT approach could produce significant economies even in the short term. Avionics modernization of existing aircraft, and GPS installation in those aircraft are areas where enforced commonality could result in substantial savings Air Force wide.

3.0 Air Force Laboratory Organization

The Air Force Laboratories are now under the control of the AFMC Product Centers. The organization was established because the Labs had become unresponsive to the needs of the operational Air Force. We believe that the decision was correct. The new organization focused the work of the Labs on problems which were important to the Air Force and, simultaneously, gave the Labs enhanced stature in the eyes of the Operational Force. The position of Air Force Technology Executive Officer (AFTEO) was established to coordinate the programs.

We believe that the current organization has served its purpose well, but the pendulum has begun its inexorable swing from improved focus to myopia. Each of the Labs has important programs which are not directly associated with its Product Center. Those programs will eventually suffer because of their being labeled as outsiders. The impact of new technologies is to demand closer integration and "flattening" of organizations to provide better integration of the technologies themselves. Recognizing that no organizational structure remains viable forever, we recommend that all the Laboratories be placed under the authority of an S&T Executive. The S&T Executive should have authority over both personnel and programs. We avoid recommending either civilian or military control. A civilian S&T Executive could provide continuity, but a military S&T Executive could provide closer ties to the operational Air Force. The S&T Executive should be, at least, at the level of a Product Center Commander, but the exact structure and identity of the S&T Executive should be the subject of further debate and study. The S&T Executive should be charged with maintaining the pressure on the S&T organization to recognize and pursue transition opportunities. The executive pressure coupled with better integration across the S&T organization should increase transition opportunities.

4.0 Personnel Practices and Opportunities

We observed that technically educated people will be extremely important to the Air Force of the 21st century.[1] Technology will touch all facets of Air Force life and operations. Although the Air Force can recruit intelligent and productive people by offering funding for advanced and undergraduate degrees, retention of those people will be possible only if career opportunities

1. Chapter II, Sec. 7.0

exist in the long term. For technically educated military personnel, it should be possible to establish a path through the Lab Commander position to Flag rank. The designation of Lab Commander as equivalent to Wing Commander will place the Lab Commander in a promotable position. If Lab Commanders have impeccable technical credentials, the young officer will feel that a technically oriented career has significant advancement possibilities. Fewer will abandon the Force for industrial jobs. We do not suggest that a technically oriented career be pursued only in Laboratories or SPO's. There should be diversification during a career. We suggest only that the majority of a career be devoted to technical matters. *The Air Force should consider career management of technically oriented officers with the same vigor as that of the rated force.*

5.0 SAB Focus

The SAB consists of 50 members. The members are assigned to a Panel such as Sciences, Avionics, etc., but in fact there is no formal organization. A part time, volunteer organization composed of scientists, technologists, and administrators truly has no need of formal organization. There is no evidence that the absence of an enforced formal structure has had any effect at all on the operation of the organization. Members respond to requests for their time to the extent that they can. Their dedication to the organization is indicated by an average yearly participation of more than 20 days. Most find the collegiality and informality of the organization refreshing, and strong friendships develop. Therefore, we believe that the organization, or lack of one, is appropriate.

The tasks performed by the members could be altered somewhat. The Board performs studies at the rate of a large summer study and one or more ad hoc studies each year. Occasionally, a small group of Board members will respond to a specific request for a study requiring three or four members to meet once or twice to consider a specific, limited issue. Also, Mission Panels respond to requests for help from a Major Command once or twice a year. A large portion of the Board's work is directed toward the quality review of Air Force Laboratory programs. We believe that all these functions are appropriate and should be continued.

Over the past few years the Board has provided members to moderate and evaluate the output of two Workshops. The first was the Laser Mission Study which was convened by Phillips Lab at the request of Maj. Gen. Robert Rankine when he was AFTEO. The study was a great success, and its recommendations are being pursued with equal success. Last year, a three day workshop on munitions with a structure similar to the Laser Mission Study was organized at the Munitions Directorate of Wright Lab. It was also judged a success in that it gave direction to Air Force efforts to develop higher energy density explosives and more effective munitions. In January or February 1996, a workshop on atmospheric propagation and compensation of laser beams will be held under the auspices of the SAB, the Naval Research Lab, and Phillips Lab. We expect the workshop to define research directions in the field.

We believe a workshop should be a yearly feature of the SAB. It is not only effective but also it amplifies the work of the Board and produces useful results with less effort on the part of the SAB Secretariat.

We also believe that the "quick look" study could be used more effectively in support of ongoing projects.

Finally, there should be a significant effort in the current year to generate a migration plan for *New World Vistas* technologies and to make the output of the *New World Vistas* study useful input to the Air Force Long Range Planning effort.

Appendix A

General Fogleman's, CSAF, and Dr. Widnall's, SecAF, memo to Dr. McCall, SAB Chair, subject: *New World Vistas* Challenge for Scientific Advisory Board (SAB), dated 29 Nov 94.

SECRETARY OF THE AIR FORCE
WASHINGTON

29 Nov 94

MEMORANDUM FOR DR McCALL

SUBJECT: New World Vistas Challenge for Scientific Advisory Board (SAB)

During the recent commemoration of the 50th anniversary of the Scientific Advisory Board (SAB), we recognized its significant accomplishments over the past half century. In addition to the high profile aircraft and weapons systems General Arnold and Dr von Karman foresaw, these two visionaries also reminded us that *"only a constant inquisitive attitude toward science and a ceaseless and swift adaptation to new developments can maintain the security of this nation."*

This reminder is even more relevant today than it was 50 years ago. There has never been a period in our country's history when "swift adaptation to new developments" was more important. One need only look at the blistering pace of computer technology and information system development to appreciate that the security of our nation depends on a "constant inquisitive attitude."

We want you to re-kindle that attitude toward science. In that spirit, we challenge the Air Force Scientific Advisory Board to search for the most advanced air and space ideas and project them into the future. Fifty years ago, the SAB was challenged with looking "Toward New Horizons." Today, we launch our search for "New World Vistas."

New World Vistas should be a truly independent, futuristic view of how the exponential rate of technological change will shape the 21st century Air Force. We'd like to begin this effort immediately, and complete the forecast within one year. Our goal is to publish New World Vistas in December 1995, on the 50th anniversary of the publication of Toward New Horizons.

New World Vistas should offer a ten year technological forecast which:

1) Predicts how the explosive rate of technological change will impact the Air Force over the next ten years. Identify fields of rapidly changing technology and assess their impact on the modern Air Force. Some possible areas to explore include the rapid advances in information, C4I, and space technology. Your challenge is to identify those areas which will most likely revolutionize the 21st century Air Force.

2) Predicts the impact of these technological changes on affordability of Air Force weapons systems and operations.

3) Predicts Science and Technology (S&T) areas where we can minimize Air Force investment and turn to the commercial world for technology development. Highlight opportunities for dual use, possibilities for defense conversion, and mechanisms for capitalizing on technology advancement in the commercial sector. Identify areas we can rely on, or partner with, commercial industry for technology development. Also, identify the areas where we are not the innovator, but a large high tech customer. Offer advice on how the Air Force can be a better customer.

4) Predicts S&T areas we will have to develop, where no commercial market exists or will likely develop. Highlight related industrial base issues.

5) Offers advice as to whether our lab structure is consistent with these new vistas, and what changes, if any, should be made.

6) Offers advice as to whether the current SAB charter is consistent with these new vistas, and what changes, if any, should be made.

7) Evaluates your proposal in light of how the Air Force contributes to the joint team.

Roughly every ten years the AF has launched a major S&T forecast. The relative success of these forecasts depends on the degree of interaction with and ***commitment of senior AF leadership.*** We are fully committed to New World Vistas. We are empowering you to tap the resources in any Air Force organization, including the Secretariat, Air Staff, Air University, or others. We would appreciate quarterly updates on your progress.

A fundamental part of Air Force culture has always been our high technology orientation. In the face of ultra-rapid technological change, the Air Force must take bold steps. New World Vistas is such a step. We know that asking you to formulate a new technological vision for the Air Force capitalizes on the strengths of the Scientific Advisory Board. We have the utmost confidence in your leadership, and anxiously look forward to your report.

RONALD R. FOGLEMAN
General, USAF
Chief of Staff

SHEILA E. WIDNALL
Secretary of the Air Force

Appendix B

Abstracts

Aircraft & Propulsion Volume Abstract

The Aircraft and Propulsion Panel was chartered to identify and recommend aircraft and propulsion technologies and concepts that have potential to favorably impact the ability of the USAF to accomplish its mission in the future.

The panel held five fact-finding meetings with DoD scientific agencies. Six attributes are identified as critical to future USAF air vehicles: affordability, lethality, flexibility, survivability, speed and range. In conjunction with the applications panels and considering these critical attributes, seven air vehicle concepts are identified to fulfill future USAF requirements: modular vehicles, uninhabited aircraft, hypersonic vehicles, future attack aircraft, large transport aircraft, special operations aircraft, and long endurance aircraft.

The key technologies required to develop these vehicle concepts have been identified and evaluated as to criticality and readiness. An overall assessment of enabling aircraft and propulsion technologies is provided along with a discussion of important infrastructure concerns including test facilities and USAF laboratory structure.

Recommendations are made for the USAF to pursue air vehicle technologies that are required to support future missions, to retain and modernize its ground test facilities and to pursue experimental and flight research programs. These actions will protect the technology base and air vehicle development capability necessary to provide air-vehicle systems superior to those of any adversary.

Dr. Richard G. Bradley, Jr.
Chair, Aircraft & Propulsion Panel
15 December 1995

Panel Membership

Dr. Richard G. Bradley, Jr., Chair
Prof. Eugene E. Covert
Dr. Douglas L. Dwoyer
Dr. William H. Heiser
Mr. William J. King
Dr. James D. Lang
Dr. James G. Mitchell
Dr. G. Keith Richey
Prof. Terrence A. Weisshaar
Capt Christopher N. Berg
Maj William B. McClure
Maj Michael K. Reagan

Attack Volume Abstract

Shaping the Air Force to meet the needs of the future is a daunting undertaking. We chose a fundamental and operationally oriented approach for revealing and defining the types of operational capabilities most relevant for any future. Stated at the most generic level, the purpose of military power is to protect the nation to the extent possible within the constraints imposed. *We seek those operational capabilities that allow us to conduct any missions, meet any contingency, and win any war.*

The role of military power is to control (dictate and enforce) the operations of all types of enemy forces. We *define* in detail the enemy operations we wish to control and the *tasks* required to achieve those objectives, *framing operational capabilities* down to the tactical level. These *tasks are* by definition *enduring, important and there is considerable opportunity and need for improvement.* Finally, we *define* the *operational concepts* to accomplish the tasks. These *concepts establish* the needed *functional capabilities*. We then, *define the systems and capabilities required to provide* these *functional capabilities*—for three time periods: 1995, 2000-2010, and 2005-2025.

Mrs. Natalie W. Crawford
Chair, Attack Panel
15 December 1995

Panel Membership

Mrs. Natalie W. Crawford, Chair
Dr. John M. Borky
Maj Gen Gerald J. Carey, USAF (Ret)
Mr. Ramon L. Chase
Mr. Jerauld R. Gentry
Mr. Dennis L. Holeman
Lt Gen Glenn A. Kent (Ret)
Mr. Sherman N. Mullin
Maj Steve W. Martin
Capt Donna J. Williams
Maj Michael K. Reagan

Directed Energy Volume Abstract

Directed energy weapons, both lasers and microwaves, will have widespread application over the next few decades. A substantial technical data base now allows confident anticipation of weapon applications. Initial airborne weapons to provide boost-phase defense against ballistic missiles and defense of aircraft against missiles will lead the way to space-based, or space-relayed, weapons. Global presence with weapons capable of destroying or disabling anything that flies as well as most unarmored ground targets will drive a new warfare paradigm.

This volume discusses directed energy applications that are most probable as well as most important in three time periods: 10, 20, and 30 years in the future. The technologies that should be supported to enable these applications are discussed leading to several conclusions and recommendations. Our intent is that these recommendations are sufficiently detailed to provide rapid definition of technology thrusts in laboratory programs. Reference is also made to a number of classified annexes that cannot be discussed herein.

Maj Gen Donald L. Lamberson (Ret)
Chair, Directed Energy Panel
15 December 1995

Panel Membership

Maj Gen Donald L. Lamberson (Ret), Chair
Dr. Clifford B. Dane
Dr. Alexander J. Glass
Dr. Gene H. McCall
Mr. John M. McMahon
Dr. Walter R. Sooy
Mr. Darrell E. Spreen
Lt Col Mike L. Crawford
2Lt Dennis S. Rand
Lt Col David G. Hincy

Human Systems/Biotechnology Volume Abstract

All Air Force systems must be human-centered, from design to operations. People are central to all Air Force activities. No matter how the battlefield of a particular future conflict evolves, and no matter what mix of power is used, there will always be a human in every loop, to exercise command and control.

Human-centered design, development, manufacturing, and fielding provide the only way to ensure maximized human performance, especially for the "most-certain-to-come" capability of fusion of the human/machine interface into one being. Air Force goals of better human information-processing and decision making, and better understanding of mental processes such as reasoning and memory, are central to situational awareness of the future battlefield, and to winning.

Air Force investment in cognitive science and neurobiology now, at the Air Force Office of Scientific Research and the laboratories, must be protected at all cost. These sciences are enabling. The huge savings in training costs, up to 50%, the huge savings in logistics management through new human-centered visualization technology, and the saving of lives through neutralization of human fatigue in combat, all flow from these enabling sciences. They enable us to win in a world where everyone has pieces of our national technological array of capabilities.

Dr. Garrison Rapmund, MD
Chair, Human Systems/Biotechnology Panel
15 December 1995

Panel Membership

Dr. Garrison Rapmund, MD, Chair
Dr. Richard F. Gabriel
Dr. Wallace T. Prophet
Dr. Adelia E. Ritchie
Dr. Henry L. Taylor
Dr. William E. Welch
Dr. Harry L. Wolbers, Jr.
Capt Teresa A. Quick
Capt Sandra M. Eisenhut
Maj Michael K. Reagan

Information Applications Volume Abstract

The US Air Force is a young service, and is about to experience its first paradigm shift. The expanded use of information systems will radically alter the tasks associated with putting energy on targets. In addition, early in the next century, warfare will take place within these same information systems.

Coupling new information systems with the global reach of the Air Force will form the basis for a potent new form of military aerospace power. Dealing with information warfare in a fundamental way will bring about a profound cultural shift in the Air Force. This shift will begin in earnest over the next decade, and may be wrenching for those imbued with the cultural heritage of manned aircraft.

To respond to these changes, the Air Force must expand its traditional role as the leading proponent of air and space power to include an equally important role in cyberspace. To the extent the Air Force can effectively unite aerospace power with information based power, it will remain a dominant factor in the defense of our nation. To help accomplish this goal, the Information Applications Panel monographs provide details of long term research and development for:

- Situation awareness
- Communications
- Battle planning and execution management
- Computer security
- Information warfare

Dr. Charles L. Morefield
Chair, Information Applications Panel
15 December 1995

Panel Membership

Dr. Charles L. Morefield, Chair
Dr. Larry E. Druffel
Dr. Vincent W. Chan
Lt Gen Lincoln D. Faurer, USAF (Ret)
Mr. Ronald D. Haggarty
Col Gerald E. Reynolds
Dr. Harold W. Sorenson
MG John F. Stewart, Jr., USA (Ret)
Maj John D. Davidson
Capt Kevin L. Taylor
Capt Dean F. Osgood

Information Technology Volume Abstract

The task of the Information Technology (IT) panel is to project the visible trends of the continuing revolution in information technology and, where projection fades at the horizon, to envision further progress. We have done this in two ways.

First, systematically we surveyed the areas of IT work. Examples are communications, computer system architectures, the interface between computers and people, software and the technologies for its development, the emergence of artificial intelligence software that emulates human-like thought processes, software that learns and adapts itself to user needs, technologies for crypto-secrecy and for assured access to systems and networks, and several more.

Second, we projected and envisioned specific achievements, stretching out over twenty years or more -- highlights of the information future. Some are evolutionary, "big wins" with high probability of being achieved. Others represent discontinuities; we do not know if they will arrive but if they do, their impact will be revolutionary. Still others represent technological, educational and organizational concerns for the future of the Air Force in the era of the information revolution.

Military needs no longer drive this revolution. The good news is often we can buy off-the-shelf hardware, software, and communications that are much better than, and very much cheaper than, what we can have custom-built for us. The Air Force is challenged to adapt to this new way of doing business, and to benefit from the best commercial technology can offer (just as our friends and enemies can). But some information technologies the Air Force needs will not emerge from the commercial marketplace. Our panel made judgments about what these will be as a set of recommendations for continued Air Force and DOD R&D funding priorities for information technology. Our panel also points out where the Air Force can benefit from starting to rethink right now how information technology can improve its weapon system design, acquisition, management, education and career development processes.

Dr. Edward A. Feigenbaum
Chair, Information Technology Panel
15 December 1995

Panel Membership

Dr. Edward A. Feigenbaum, Chair
Dr. Barry W. Boehm
Dr. Randall Davis
Prof. John E. Hopcroft
Dr. Robert W. Lucky
Dr. Donald L. Nielson
Mr. Paul Saffo
Prof. Gio Wiederhold
Col Roderick A. Taylor
Col Harvey D. Dahljelm
Maj M. Clarke Englund
Maj Earl H. McKinney
Capt Dean F. Osgood

Materials Volume Abstract

Air Force battlefield superiority is maintained, to a significant extent, by the use of advanced materials that enable weapons and weapons platforms to accomplish specific aerospace missions. The driver for the introduction of new materials in the past has been improved performance, and performance will continue to be the driver in the future. We are now entering an age when these materials will be designed to have specific properties using advanced computational techniques at the atomic/molecular level. The Air Force must strive to maintain a leadership role in new materials science and technology, because it is unlikely that commercial suppliers could meet critical Air Force needs in the absence of large commercial markets. The Air Force must also develop pathways for the more rapid introduction of new material into new and existing flight systems; these pathways must enable the introduction of new materials in a rational manner even if significant initial risk exists. Finally, in light of tightening environmental regulations, the Air Force should move to life cycle costing to ensure that the cost of disposal or recycling of specific materials is adequately covered and will not become a burden on future Air Force budgets.

Prof. Digby D. Macdonald
Chair, Materials Panel
15 December 1995

Panel Membership

Prof. Digby D. Macdonald, Chair
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Dr. Douglas S. Dudis
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Dr. Robert A. Hughes
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Mobility Volume Abstract

The political changes around the world result in US forces being primarily based in the US. Consequently, heavier demand falls on the Mobility Command to provide true global reach and global power. After reviewing the needs associated with this requirement, the Mobility Panel selected five areas embodying revolutionary technology to improve mobility.

1. Information Dominance -- world-wide communications, information on demand in the cockpit, and intransit visibility of cargo.
2. Global Range Transport -- new airplane weighing about 900,000 pounds, carrying 150,000 pounds cargo for 12,000 nautical miles unrefueled.
3. Precision/Large Scale Airdrop -- 100 foot accuracy, integral wind sensing, family of airdrop systems.
4. Directed Energy Self Defense Weapon -- a kilojoule laser system to defeat ground-to-air and air-to-air missiles.
5. Virtual Reality Applications -- use of holographic displays, synthetic sensory environment, communication networks, etc. for mission training.

The key technologies needed to attain these capabilities are: 1) accurate, timely, and dependable information through computer controlled satellite and fiber optic networks, 2) high temperature materials for advanced turbofan engines, 3) low cost composites for airframes, 4) airborne laser, 5) airborne wind-measurement sensors, and 6) synthetic environment generation.

Mr. Robert J. Patton
Chair, Mobility Panel
15 December 1995

Panel Membership

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Mr. Richard J. Busch
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Munitions Volume Abstract

The Munitions Panel identified several high payoff munitions concepts that address recognized and future US defense needs. The weapon concepts are achievable within the next 10-30 years and will significantly enhance the warfighting capabilities of the US Air Force. In general, we focused on smaller, lighter, agile, more lethal, and more affordable weapons that respond to a spectrum of Air Force missions and the target strike capability of delivery platforms. Some of the enabling technologies for these weapon concepts exist today, others are just ahead, and certain key ones await fundamental breakthroughs in technologies. Combined with innovative and creative approaches to weaponry design, all offer significant enhancements to Air Force warfighting.

The following recommendations will effectively exploit and implement the high pay off munition concepts identified to address projected US defense concerns: an Airborne Interceptor Missile to counter theater ballistic missiles; an RF Attack Cruise Missile to prevent enemy electronic operations; a Self Protect Missile for aircraft self defense; Autonomous Miniature Munitions to stop invading armies; an Airborne Interceptor Missile to counter low observable cruise missiles; Hard Target Munitions and Robotic Micro Munitions to attack deeply buried hard targets; and a Hypersonic Missile to attack quickly.

As an example of the importance of these concepts, we highlight autonomous miniature precision munitions which are small, self piloting, highly lethal munitions. These are capable of halting advancing armies because they are capable of autonomous target acquisition and classification. They incorporate adaptable warheads appropriate for a wide range of soft and hard targets. The autonomous precise miniature munitions offer a powerful way to defeat enemy forces rapidly. The conventional strategic bomber and tactical aircraft force could deliver over 20,000 self targeting munitions in one strategic tactical raid -- shutting down enemy forward air defenses, halting his armored assault, suppressing surface-to-surface missile operations, and impeding second echelon forces.

Additionally, key enabling technologies and capabilities are identified with specific science and technology approaches. Further, we have specified several munitions technology integrating concepts, and finally, we cite next step actions to implement the most important munition concepts.

Mr. Milton Finger
Chair, Munitions Panel
15 December 1995

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Dr. Joe C. Foster
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Dr. Robert W. Selden
Dr. Michael Shatz
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Sensors Volume Abstract

"To Know More and to Know It Sooner"

Sensors are essential elements of virtually every Air Force weapon and support system. The hardware and software associated with sensing functions are generally major, and sometimes predominant, contributors to the performance, reliability, supportability, and cost of such systems. They can exploit the full electromagnetic spectrum by intercepting reflected or naturally occurring electromagnetic radiation, detect various forms of mechanical energy (e.g., seismic and acoustic), and physically sample and analyze a diverse set of chemical and biological components. Many of the technologies associated with sensors are in a state of rapid evolution and will remain so for the foreseeable future. Moreover, many sensing functions and devices that are important to the Air force have counterparts in commercial, industrial, and medical applications. This combination of ubiquity, operational impact, technology leverage, and dual use potential makes the subject of sensors especially important to the themes of *New World Vistas*.

The Sensors Volume describes the future of sensors from the viewpoints of operational pull and technology push. Operational tasks that stress current sensors are described along with key enabling technologies. Seven illustrative sensor system concepts are then presented to indicate the importance of integration of multiple sensors. Finally, based on a survey of the overall sensor technology arena, nine high potential technology areas are described in some detail.

Dr. Jack L. Walker
Chair, Sensors Panel
15 December 1995

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Space Applications Volume Abstract

The application of space in future military operations will facilitate global presence, knowledge on demand, space control and power projection.

Successful integration of space with information based warfare capabilities will be critical to maintaining information dominance of the battle space and winning at information warfare. Key capabilities are space-based observation, space communications, and global positioning, mapping and time transfer.

The proliferation of commercial space systems gives our adversaries unprecedented access to militarily significant capabilities that will reduce the information advantage our forces presently enjoy.

The need to disrupt, deny and influence the enemy's perception of the battle space while assuring our use for information based warfare is essential, and thus space control takes on new significance in this environment.

In the future to support global presence it will become feasible to project force from space directly to the earth's surface or to airborne targets with kinetic or directed energy weapons.

All of this is possible with the continued improvement of space systems operations with reduced manpower at lower cost, design of spacecraft with modern low cost techniques, adaptation of innovative architectures incorporating distributed satellite systems and the development of affordable access to space.

Dr. Michael I. Yarymovych
Chair, Space Applications Panel
15 December 1995

Panel Membership

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Mr. David W. Thompson
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Space Technology Volume Abstract

The Space Technology panel's recommendations for technology investments derive from a vision of the Air Force in space in the 21st century, in which the Air Force has achieved survivable, on demand, real time, global presence that is affordable. This vision represents a revolutionary increase in capabilities for the Air Force and is achievable with targeted Air Force technology investments and adaptation of commercial developments.

Several key technologies offer the possibility of a substantial increase in the exploitation of space by the Air Force, the potential impact of which is so great that the Air Force must invest now. These technologies are:

- High-energy-density chemical propellants to enable spacelift with high payload mass fractions—specific impulses of 1000 seconds or greater (in high-thrust systems) should be the goal of this effort
- Lightweight integrated structures combining reusable cryogenic storage, thermal protection, and self diagnostics to enable a *responsive* reusable launch capability
- High-temperature materials for engines and rugged thermal protection systems
- High performance maneuvering technologies such as electric propulsion (with thrusts greater than tens of Newtons at specific impulses of thousands of seconds at near 100% efficiency - the goal for electric propulsion) and tethers for momentum exchange
- Technologies for high power generation (greater than 100 kilowatts) such as nuclear power, laser power beaming, and electrodynamic tethers
- Technologies for clusters of cooperating Satellites (e.g., high-precision stationkeeping, autonomous satellite operations, and signal processing for sparse apertures)

Prof. Daniel E. Hastings
Chair, Space Technology Panel
15 December 1995

Panel Membership

Prof. Daniel E. Hastings, Chair
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Classified Volume Abstract

The classified volume report is a compilation of classified material (text and charts) that could not be discussed in this Summary Volume nor in any of the 12 unclassified panel report volumes. The panels that wrote material containing sections of classified material found in this volume and referenced in their volumes are: Munitions, Space Applications, Directed Energy, and Information Applications. A brief unclassified description of some of the topics found in this volume are provided below:

- **Munitions** - A concept of preventing enemy electronic operations using radio frequency (RF) attack cruise missiles; and a concept of using a self-protect missile for aircraft survivability. Over the past decade, electromagnetic technology has been sufficiently developed to consider practical development of weapons of this kind.
- **Space Applications** - An emphasis on space control capabilities, both offensive and defensive, are discussed as possible means in future warfare. These means could be applied to any element of the space system to include: the ground capabilities; the spacecraft links; the spacecraft itself; and the processing and distribution of the information. Also, a discussion of space tethers as a spacecraft survivability concept is provided.
- **Directed Energy** - Various concepts of directed energy weapon systems playing a role or as a means of future space control or supporting military missions are discussed.
- **Information Applications** - In the widely distributed global information system of the future, it will be difficult to determine sources of adversary information. This section discusses technologies and concepts for intelligence gathering and information attack in the commercially based, distributed global information system of 2025.

Ancillary Volume Abstract

In November 1994, the Secretary of the Air Force, Honorable Sheila E. Widnall and the Air Force Chief of Staff, General Ronald R. Fogleman, challenged the Air Force Scientific Advisory Board to "rekindle their inquisitive attitude" which had originated one half century before when Dr. Theodore von Kármán was tasked by General of the Army, Hap Arnold, to look to the future and make a report—a blueprint—on which to build an independent Air Force . As part of this current study, *New World Vistas*, Dr. Gene McCall, SAB Chairman, asked the members of the Board to take an individual shot at the future. The nature of forecasting in the Air Force has gone through many iterations. The first forecast was produced by only 31 of the nation's finest minds. The current forecast team is nearly five times that size. But times have changed.

Today, it is no longer possible to gather the majority of America's aeronautical scientists in one university auditorium. The surreal explosion of computer technology and the expansion of aeronautics into astronautics, and all of the disciplines which are related to advances in these areas, makes comprehensive individual reports a true impossibility. No longer can one scientist know all there is to know in one field of study.

But many scientists will tell you that, every once in a while, an individual brilliant thought triggers a breakthrough. This is the purpose behind these essays. Perhaps in reading these individual thoughts about the future, a moment of brilliance will result within you and trigger a breakthrough in your field . It may not happen this year or in ten years, but it might happen someday. Fifty years ago this kind of individual thought resulted in the creation of *Toward New Horizons*, the blueprint upon which was built the supremacy of today's Air Force.

This volume contains these essays and several interviews conducted by Mr. Jim Slade and Maj Dik Daso during the production of a one hour video program dedicated to the 50 year history of the USAF Scientific Advisory Board.